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SURVEY OF BOTTOM FISH RESOURCE IN THE
NORTHWESTERN HAWAIIAN ISLANDS

by

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INTRODUCTION

In 1969, the Governor's Task Force on Oceanography of the State of Hawaii recognized a need to explore, inventory, and develop new fishing areas to relieve the fishing pressure being exerted on the marine resources around the principal inhabited islands of Hawaii. The obvious place to explore was the Northwestern Hawaiian Islands (NWHI), a part of the Hawaiian Archipelago extending 3,200 km in a southeast-northwest direction.

Compounding the need for an investigation of the NWHI resources was the enactment of the U.S. Fishery Conservation and Management Act (FCMA) of 1976 (Public Law 94-265), which extended U.S. jurisdiction over fishery resources 200 nmi from our nation's coastline. As management plans were being considered for various species of fish and shellfish in the Fishery Conservation Zone (FCZ) around Hawaii, it became abundantly clear that there was little information of the operational aspects of the fisheries and that, in some cases, nothing was known about the resources in the NWHI.

Realizing that the scope of the NWHI investigation was beyond the capabilities of the staff and facilities of any single research agency in Hawaii, the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service proposed a cooperative research effort with the State of Hawaii's Division of Fish and Game (HDFG) and the U.S. Fish and Wildlife Service (USFWS). The result was the signing of a Tripartite Cooperative Agreement, which provided for a survey and assessment of the nearshore fishery resources by the HDFG, biological studies and inventory of land-associated seabirds by the USFWS, and quantitative fishery

assessment and survey of the benthic slope and pelagic resources by the Honolulu Laboratory

BACKGROUND

The marine fauna in the Hawaiian Archipelago is an offshoot of that great marine geographic region centered on the East Indies. In Hawaii, the species complex is not as diverse as that in the western Pacific and the neritic shelf zone, unlike that of the world's great fishing areas is narrow and poorly developed. As a result, of the approximately 682 species of fish found in Hawaii, only about 60, mostly occurring on the reefs and benthic slopes, are commercially exploited.

The bottom fish resource in Hawaii includes a wide variety of fish. Those of high commercial value, mainly members of the snapper-grouper complex, include pink snappers, Pristipomoides filamentosus and P. sieboldii, Brigham's snapper, P. zonatus, red snappers, Etelis carbunculus and E. marshi, sea bass, Epinephelus quernus, gray snapper, Aprion virescens, members of the family Carangidae including amberjack, Seriola dumerilii, blue crevally, Caranx melampygus, white crevally, C. ignobilis, and thick-lipped crevally, C. cheilio, and members of the goatfish family, Mullidae.

SAMPLING PROCEDURES AND EFFORT

Between October 1976 and June 1979, 13 cruises were completed in the waters around the NWHI, including 11 by the NOAA ship Townsend Cromwell and 2 by a chartered fishing vessel. During these cruises, we occupied 91 bottom trawling stations, 125 handline fishing stations, and 97 fish trapping stations.



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In addition to the data collected on the Cromwell and on chartered vessels, the Honolulu Laboratory established a commercial vessel observer program to collect field data from commercial vessels fishing in the NWHI. Detailed records of catch by species, fishing effort, and sizes are recorded on standard log forms by Honolulu Laboratory observers on board the vessels. Data collected by these observers are essential for stock assessment.

AREA AND SEASONAL COVERAGE

To analyze the distribution of fishing effort and catches of bottom fish, the area around the NWHI was divided into squares, each square measuring 6 min to a side of latitude and longitude. The squares were identified by their latitude and longitude at the lower right corner.

Although it was highly desirable to systematically survey as many of these squares as practical and to repeat the surveys to obtain good seasonal coverage, it was impractical to do so mainly because of time limitations. However, during the 3 yr just completed, we believe that adequate coverage has been given to the major islands such as Necker Island and Maro Reef where commercial quantities of spiny lobsters, Panulirus marginatus, have been discovered.

In terms of areal coverage, it has been estimated that the FCZ around the NWHI consists of an area roughly 1.8×10^6 km². Of this total about 20,900 km² or about 1% lies within the 366-m (200-fathom) contour where most of our bottom fish research is carried out.

BOTTOM TRAWLING

Our initial trawling effort was conducted with a high opening "Norwegian" fish trawl, which has a 20-m headrope, a 25-m footrope, and 36-cm diameter roller. On our more recent survey cruises, we have been using a larger "Noreastern" trawl, which has a 27-m headrope, a 32-m footrope, together with a pair of 1.8×2.7 m steel V-type doors. This trawl is used with a net sonde which permits us to monitor the depth of fishing and to avoid loss of the net over rough bottom. The "Noreastern" trawl has been particularly effective in sampling the seamount groundfish resource at Hancock Seamounts consisting mainly of armorhead, Pentaceros richardsoni, and alfonsin, Beryx splendens.

Trawl hauls varied from 15 to 30 min. Among the commercially valuable species caught in the trawl hauls were mackerel scad, Decapterus russellii, red bigeye, Priacanthus cruentatus and Cookeola boops, goatfishes, Parupeneus spp. and Mulloidichthys vanicolensis, pink snapper, Pristipomoides filamentosus, unicornfish, Naso unicornis, thick-lipped crevally, C. cheilio, amberjack, S. dumerilii, sea bass, E. quernus, spiny lobster, Panulirus marginatus, and slipper lobster, Scyllarides squammosus.

HANDLINE FISHING

When the NWHI survey was first begun in the fall of 1976, commercial handline gear similar to that used in the Hawaiian fishery was used. The mainline consists of braided dark-brown nylon line varying in strength from 65 to 120 kg. The mainline is joined to a monofilament drop line (90 kg test) to which are attached 4-5 monofilament hook lines (45 kg test)

spaced about 1.8 m apart; a 1.4 kg weight is attached to the end of the drop line. The hook line is about 1 m long. Hooks, which vary in size from No. 18 to No. 32, are Hawaiian-type recurved "oio" hooks.

To reduce the labor-intensive hand method of line hauling, hydraulic-powered reels or gurdies were used. The power reels, which proved to be extremely versatile and useful for bottom fishing, includes a davit with block, a rotating base, and brake and clutch assembly to control descent and ascent. We also experimented with electric reels, but these were abandoned after a few cruises because of the limited spool capacity.

Handline fishing stations are occupied day or night and usually lasts from 1 to 4 h. At each station, about four lines are fished although occasionally, as many as six lines have been fished at one time. During fishing, the vessel usually is allowed to drift from shallow to deeper waters or vice versa. A drift course parallel to a particular depth contour is desirable but rarely attainable.

FISH TRAPPING

Although several different types of fish traps were used in preliminary surveys in the NWHI, we eventually selected the rectangular, single compartment "Hawaiian-type" traps, which were made of 1.3-cm reinforcing steel frame measuring 152.4 cm long, 91.4 cm wide, and about 60.9 cm high. The trap was covered with 2.5-cm square galvanized wire mesh. This trap was modified by the addition of an off-center panel of wire mesh 50.8 cm from one end of the trap to create two compartments. The chamber, the shorter of the two compartments, has an entrance on both sides. Each entrance is

conical and has an outer diameter of 30.0 cm and an inner diameter of 16.5 cm. From the chamber, the parlor or the larger of the two compartments, which has the bait box, is entered through a third conical entrance of the same dimensions as those used to enter the chamber from the outside.

Smaller fish traps, which were lighter and easier to handle on the deck of the vessel, were constructed for cruises in 1979. These traps, essentially a scaled-down version of our original traps and with identical funnel openings, measured 108.0 cm long, 77.5 cm wide, and 46.3 cm high. The traps were covered with 2.5 cm $\times$ 1.2 cm hardware cloth.

Because fish traps were used in combination with lobster pots, most of them were set in the evening at about 1800 h, soaked overnight for about 14 h, and hauled the following morning after 0800 h.

PRELIMINARY RESULTS OF BOTTOM FISH RESEARCH

Among the ongoing research on the bottom fish resources in the NWHI are studies on distribution and relative abundance, fecundity, spawning season, age and growth, ciguatera, food and feeding habits, morphometric comparison, and population dynamics.

Relative Abundance

Preliminary results based on five cruises indicated that Pearl and Hermes Reef, located about 1,931 km northwest of Honolulu, is highly productive with an overall catch rate of about 2.8 fish/line-h. Other areas that showed relatively high productivity included Nihoa Island (2.3 fish/line-h), French Frigate Shoals (1.8 fish/line-h), Midway and Maro Reef (about 1.6 fish/line-h), and Necker and Lisianski Islands (1.5 and

1.4 fish/line-h). Gardner Pinnacles, Laysan Island, Raita Bank, Kure Island, and Brooks Bank all had catch rates of 1.2 fish/line-h or less.

Fecundity

Studies on fecundity were started in the past few months and have not advanced far enough to draw any conclusions; however, some of our preliminary findings indicate that ova development in the pink snapper, Pristipomoides filamentosus did not appear to be homogeneous throughout the ovary and that large ova showing the most advanced development appeared to be concentrated toward the center of the ovary. It was also determined that maturing ova in the pink snapper have a mean diameter of 0.51 mm whereas ripe ova have a mean diameter of 0.55 mm.

Food Habits

Concerning our efforts to study food and feeding habits of the fishes of the snapper-grouper complex, we have been having considerable difficulty collecting sufficient samples for analysis. Many of these fishes are taken from depths ranging between 90 and 275 m and when they are brought to the surface, expansion of the gas bladder forces the stomachs to evert and much of the stomach contents are lost.

Ciguatera

One of the major thrusts of our research on bottom fish for the past 3 yr has been a study of the occurrence and distribution of ciguatoxic fishes in NWHI waters. This study was initiated primarily because of the

concerns of the U.S. Navy, which administers Midway Islands, on ciguatera outbreaks among its naval and civilian personnel stationed at the base. As a result of these outbreaks, the U.S. Navy placed restrictions on catching and consuming fish that occurred in the lagoon waters.

Initially, our systematic sampling included the collection of tissue samples from all commercially valuable fish species caught in NWHI waters. From each fish, tissue samples were collected from the dorsal musculature, the ventral abdominal musculature, the gonads, and the liver. Subsequently, liver collection was discontinued and additional muscle tissues are being collected from near the anal region.

Each tissue sample is placed in a plastic vial, labeled, and frozen. Data collected on the fish include date, catch location, water depth, sex, length, and weight. The samples are processed at the University of Hawaii's John A. Burns School of Medicine, Pathology Department, where a practical, sensitive, and relatively specific radioimmunoassay (RIA) for the detection of ciguatoxin has been developed (Hokama et al. 1977). The toxicity levels of the fish tissues are determined from radioactive counts per minute per gram of tissue (c/m/g tissue), as follows: <350,000 c/m/g tissue - negative; 350,000-39,999 c/m/g tissue - borderline; and >400,000 c/m/g/ tissue - positive.¹

From 1977 to 1978, the Honolulu Laboratory collected tissue samples from 751 fish and the HDEG collected additional tissue samples from 253 inshore fish (total, 1,004 fish) representing 80 different species. The

¹Hokama, Y. 1979. Development and testing of fishes for ciguatoxin. Final project report submitted to the State of Hawaii, Office of the Marine Affairs Coordinator, 9 p.

RIA tests showed that 150 fish of some 39 different species were either positive or borderline positive, indicating that the detected levels of ciguatoxin could be hazardous to humans (14.9%). There is, however, a possibility that some of the samples tested may have given a false positive reaction.

The rejection rate (in parenthesis) of some of the species where 10 or more fish were tested is as follows: C. cheilio (7.4%), C. ignobilis (12.3%), C. speciosus (7.1%), S. dumerilii (12.0%), Bodianus bilunulatus (38.5%), Cheilinus rhodochrous (68.8%), Lutjanus kasmira (17.4%), P. filamentosus (15.3%), Kuhlia sandvicensis (37.0%), Muraenidae (26.3%), Mugil cephalus (50.0%), and Polydactylus sexfilis (6.7%). Table 1 gives the results of other species tested.

Table 1

In the spring of 1979, following a sudden outbreak of ciguatera among the local populace, the Honolulu Laboratory also began a project of routinely sampling and pretesting amberjack destined for sale at Honolulu's fresh fish auction market. By mid-April 1979, information supplied by various government agencies and fish retailers indicated that about 30-35 recent outbreaks could be documented and that perhaps another 50-100 individuals were affected but had not reported it to the health authorities. Whereas several finfish were implicated in ciguatera attacks in past years, a high percentage of the 1979 outbreaks appeared to be traceable to amberjack.

The previously developed RIA test for ciguatoxin was again used to analyze the amberjack tissues. In addition, an experimental enzyme-linked immunosorbent assay (ELISA) for detecting ciguatoxin is in progress in hopes of simplifying the test for future use by the commercial fishing industry.

From April 17 to August 14, 1979, 534 amberjacks were sampled at the auction market and the tests indicated that 35 were positive and 59 were borderline in toxicity, or a total of 94 (17.6%) had detectable levels of ciguatoxin.

Whereas the percentage of toxic fish in the samples was relatively high in May immediately after sampling began, it decreased in subsequent months and the percentage of rejection in August was about 5%, down from about 20% when the project was initiated. Preliminary results also indicate that very little, if any, correlation exists between fish size and RIA values, and between RIA and ELISA values. Research to improve the ELISA test is currently underway at the University of Hawaii.

Age and Growth

Another important study being conducted on members of the snapper-grouper complex is that dealing with age and growth. Pioneering research conducted in Puerto Rico by Pannella (1974) on the use of otoliths to age tropical fish was followed by several studies in the central Pacific, particularly in Hawaiian waters (Struhsaker and Uchiyama 1976; Ralston 1978; Moffitt²; Uchiyama and Struhsaker³).

²Moffitt, R. B. 1979. Age, growth and reproduction of the kumu, Parupeneus porphyreus Jenkins. Unpubl. rep. Dept. Zoology, Univ. Hawaii, Honolulu.

³Uchiyama, J. H., and P. J. Struhsaker. Age and growth of skipjack tuna, Katsuwonus pelamis, and yellowfin tuna, Thunnus albacares, as indicated by daily growth increments of sagittae. Manuscr. in prep. Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

Otoliths are extracted at sea or in the laboratory from frozen specimens brought back from our field surveys. Data collected with the otoliths include species, date of capture, catch locality, length, weight, and sex.

Whole-mounted or sectioned otoliths are read under a compound microscope at magnifications varying from 300X to 800X. Although we have made counts on several species, we have yet to demonstrate that a 1:1 relationship exists between age in days and the number of growth rings; however, on the basis of evidence from previous studies on other tropical species in Hawaiian waters, we are working under the assumption that each growth increment counted in the otolith represents 1 day. Attempts to corroborate this assumption will be made in the near future by tetracycline injections of live fish.

ig. 1

Much of the results of our age and growth project, therefore, are preliminary. A von Bertalanffy growth curve has been fitted to daily ring counts obtained for the amberjack (Figure 1). This growth is based on data from only six fish and a more realistic estimate will become possible only after data are obtained from additional specimens. Also, the validity of the 1:1 relationship for amberjack will have to be justified.

Aging of other species is also underway. The study on the pink snapper, Pristipomoides filamentosus, is complicated by what appears to be differential growth due to sex. Males appear to grow slightly faster than females. Other species that are being studied are the sea bass, E. quernus, pink snapper, P. sieboldii, red snappers, Etelis carbunculus and E. marshi, and thick-lipped crevally, Caranx cheilio.

SUMMARY

The Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, in cooperation with the Hawaii Division of Fish and Game, the U.S. Fish and Wildlife Service, and the University of Hawaii Sea Grant Program, has embarked on an extensive investigation of the living marine and terrestrial resources of the NWHI. Among the bottom fish resources under investigation are such species as snappers, groupers, carangids, goatfishes, armorhead, and alfonsin. Sampling is conducted primarily from the NOAA ship Townsend Cromwell using bottom trawls, handline gear, and traps.

Results of bottom fish research to date indicate that Pearl and Hermes Reef is highly productive with overall catch rates of 2.8 fish/line-h. Catch rates from other localities in the NWHI varied from 2.3 to less than 1.2 fish/line-h.

Research on distribution and occurrence of ciguatoxic fishes in the NWHI has been accelerated considerably by the development of a practical sensitive, simple, and relatively specific RIA test. Of 1,004 fish representing 80 different species tested from 1977 to 1978, 150 fish, representing 39 species showed relatively high levels of ciguatoxin. A possibility exists that some of the samples produced false positives.

Amberjack landed at the Honolulu fish auction market also came under scrutiny after several outbreaks of ciguatera were reported to local health authorities. In April-August 1979, 94 out of 534 amberjack tested (17.6%) showed either a positive or borderline level of toxicity, necessitating rejection of the fish for human consumption.

Age and growth studies based on counts of growth increments in otoliths have concentrated on commercially valuable fish of the snapper-grouper complex. A 1:1 relationship between age in days and number of growth rings has yet to be demonstrated for the species under consideration. Preliminary estimates indicate that amberjack attain a length of 35 cm in 12 mo and 56 cm in 18 mo. For pink snapper, Pristipomoides filamentosus, males appear to grow slightly faster than females.

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Table 1.--Number and percentage of fish, by species, caught in waters of the Northwestern Hawaiian Islands and found by radioimmunoassay to have toxic and borderline levels of ciguatoxin, 1977-78.

Species	Nontoxic	Borderline	Toxic	Total fish	Total borderline and toxic	Percent borderline and toxic
Acanthuridae						
<u>Acanthurus leucopareius</u>	1	0	0	1	0	0.0
<u>A. nigroris</u>	5	1	2	8	3	37.5
<u>A. triostegus</u>	11	1	1	13	2	15.4
<u>A. xanthopterus</u>	1	0	0	1	0	0.0
<u>Ctenochaetus strigosus</u>	8	0	0	8	0	0.0
Holocentridae						
<u>Adioryx lacteoguttatus</u>	2	0	0	2	0	0.0
<u>A. sammara</u>	1	0	1	2	1	50.0
<u>A. spinifer</u>	2	0	0	2	0	0.0
<u>A. xantherythrus</u>	1	0	0	1	0	0.0
<u>Myripristis amaenus</u>	7	0	1	8	1	12.5
<u>M. murdjan</u>	7	0	0	7	0	0.0
Carangidae						
<u>Carangoides ferdau</u>	7	1	0	8	1	12.5
<u>Caranx sp.</u>	1	0	0	1	0	0.0
<u>C. cheillo</u>	88	5	2	95	7	7.4

Table 1.--Continued.

Species	Nontoxic	Borderline	Toxic	Total fish	Total borderline and toxic	Percent borderline and toxic
<u>C. ignobilis</u>	57	4	4	65	8	12.3
<u>C. lugubris</u>	2	1	3	6	4	66.7
<u>C. melampygus</u>	4	1	3	8	4	50.0
<u>C. speciosus</u>	13	0	1	14	1	7.1
<u>Decapterus pinnulatus</u>	3	1	0	4	1	25.0
<u>Elagatis bipinnulatus</u>	1	0	0	1	0	0.0
<u>Seriola dumerilii</u>	73	3	7	83	10	12.0
<u>Trachurops crumenophthalmus</u>	3	0	2	5	2	40.0
Serranidae						
<u>Epinephelus quernus</u>	87	6	7	100	13	13.0
Labridae						
<u>Anampses cuvieri</u>	1	0	1	2	1	50.0
<u>Bodianus bilunulatus</u>	8	0	5	13	5	38.5
<u>B. oxycephalus</u>	2	0	0	2	0	0.0
<u>Cheilinus rhodochrous</u>	5	1	10	16	11	68.8
<u>Coris venusta</u>	1	0	0	1	0	0.0
<u>Epibulus insidiator</u>	1	0	0	1	0	0.0
<u>Macropharyngodon</u> sp.	1	0	0	1	0	0.0

Table 1.--Continued.

Species	Nontoxic	Borderline	Toxic	Total fish	Total borderline and toxic	Percent borderline and toxic
<u>Stethojulis</u> sp.	1	0	0	1	0	0.0
<u>Thalassoma ballieui</u>	3	1	0	4	1	25.0
<u>T. duperreyi</u>	1	0	1	2	1	50.0
<u>T. purpureum</u>	8	0	0	8	0	0.0
<u>T. umbrostigma</u>	1	0	0	1	0	0.0
Lutjanidae						
<u>Aprion virescens</u>	1	1	0	2	1	50.0
<u>Etelis carbunculus</u>	4	0	1	5	1	20.0
<u>E. marshi</u>	51	0	0	51	0	0.0
<u>Lutjanus kasmira</u>	57	6	6	69	12	17.4
<u>Pristipomoides filamentosus</u>	116	13	8	137	21	15.3
<u>P. sieboldii</u>	12	0	0	12	0	0.0
<u>P. zonatus</u>	20	0	0	20	0	0.0
Kuhliidae						
<u>Kuhlia sandvicensis</u>	34	6	14	54	20	37.0
Muraenidae						
	14	1	4	19	5	26.3

Table 1.--Continued.

Species	Nontoxic	Borderline	Toxic	Total fish	Total borderline and toxic	Percent borderline and toxic
Mugilidae						
<u>Mugil cephalus</u>	6	2	4	12	6	50.0
<u>Neomyxus leuciscus</u>	2	0	0	2	0	0.0
Mullidae						
<u>Mulloidichthys flaviolineatus</u>	3	0	3	6	3	50.0
<u>M. vanicolensis</u>	1	1	0	2	1	50.0
<u>Parupeneus bifasciatus</u>	1	0	0	1	0	0.0
<u>P. cyclostomus</u>	2	0	1	3	1	33.3
<u>P. multifasciatus</u>	7	0	0	7	0	0.0
<u>P. pleurostigma</u>	2	0	0	2	0	0.0
<u>P. porphyreus</u>	4	1	0	5	1	20.0
<u>Upeneus arge</u>	1	0	0	1	0	0.0
Polynomidae						
<u>Polydactylus sexfilis</u>	14	0	1	15	1	6.7
Priacanthidae						
<u>Priacanthus sp.</u>	0	1	0	1	1	100.0
<u>P. cruentatus</u>	2	0	0	2	0	0.0
Scaridae						
<u>Scarus spp.</u>	4	1	2	7	3	42.8

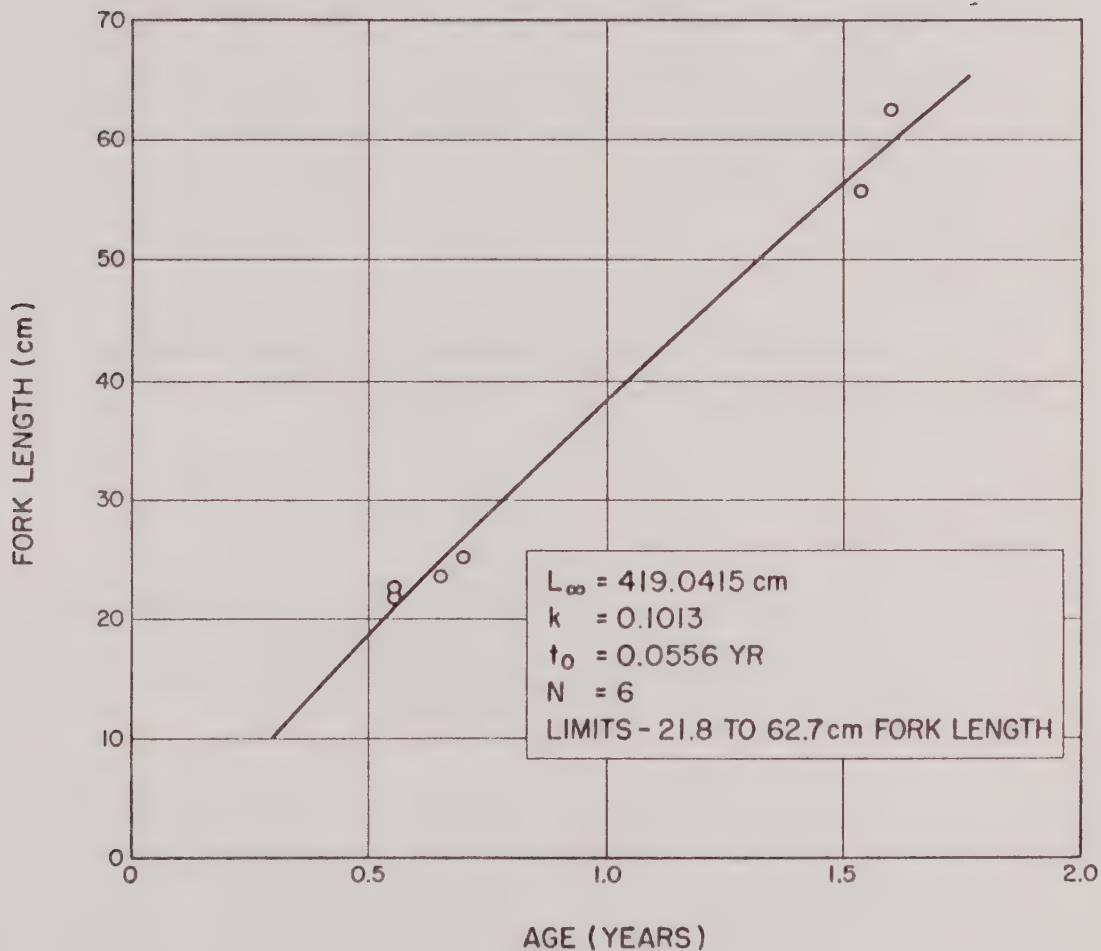


Figure 1.--Preliminary age and length relationship of amberjack, Seriola dumerilii, based on examination of growth increments in the otoliths.

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CURRENT STATUS OF FISHERIES IN THE HAWAIIAN ISLANDS

by

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INTRODUCTION

Various aspects of commercial fishing in Hawaii can be traced back to ancient Hawaiian civilization, which was intimately tied to the sea. Because of their knowledge of fishing techniques, equipment, and life history aspects of many marine plants and animals, ancient Hawaiian fishermen were regarded as professionals and held in high esteem among the native villagers (Hobson and Chave 1972). The successive waves of foreign immigrants who brought alien fishing techniques with them led to the dilution of the influence of Hawaiian culture in fishing; nevertheless, traces of ancient Hawaiian culture in fishing techniques still persist. Some of the fishing methods introduced by the early immigrants together with Hawaiian cultural influences still exist today, such as in the pole-and-line and live-bait technique used in the fishery for skipjack tuna, Katsuwonus pelamis.

Today, despite occasional outcries that commercial fishing is moribund in Hawaii, there are still nearly 2,300 part-time and full-time licensed Hawaiian fishermen, some of whom manage ample financial returns for their effort. Compared to workers in other industries, however, the Hawaiian commercial fishermen's annual income is still relatively low despite the high prices charged for fish and fishery products. Fish in Hawaii today is a luxury food rather than a daily necessity as it was in ancient Polynesia (Manar 1969).

COMMERCIAL FISHERIES

Hawaii's commercial fisheries may be divided into two major categories--the offshore, pelagic fisheries conducted by the larger vessels such as those used in tuna fishing and the inshore, benthopelagic and demersal fisheries prosecuted by smaller crafts such as those engaged in mackerel purse seining, handline fishing, and trapping.

The Offshore Fisheries

Of all the fish species found in Hawaiian waters, the one most heavily exploited and believed to have the highest potential for future expansion, is the skipjack tuna. Every year, landings of skipjack tuna far exceed those of other species in the Hawaiian catch. From 1961 to 1978, for example, landings of skipjack tuna, which varied between 2,292 and 7,329 MT (metric tons) (average, 4,170 MT), represented about 69% of the State's total marine and pond catches. In addition, skipjack tuna represented about 85%, by weight, of all tunas landed.¹

The present skipjack tuna fleet includes 15 vessels which are mostly old, wooden sampans built between 1927 and 1955. Only two steel-hulled vessels operate in the fishery--one built in 1947 and the other, a relatively recent addition, a 30.5-m vessel built in 1971. Skipjack tuna vessels range in size from 18 to 28 m in registered length and vary from 33 to 150 MT. They are capable of carrying between 6 and 14 men per fishing trip (Uchida 1967; Uchida and Sumida 1973).

¹Data are from Hawaii Division of Fish and Game, commercial fish catch, by species, 1961-78. (Mimeogr.)

The longline fishery for deep-swimming tunas and billfishes represents the second most important fishery in the Hawaiian Islands. Major species landed include yellowfin tuna, Thunnus albacares, bigeye tuna, T. obesus, albacore, T. alalunga, striped marlin, Tetrapturus audax, Pacific blue marlin, Makaira nigricans, black marlin, M. indica, broadbill swordfish, Xiphias gladius, sailfish, Istiophorus platypterus, and wahoo, Acanthocybium solandri. Of these, three species--yellowfin tuna, albacore, and wahoo--have shown significant increases in statewide landings in recent years; however, the increases are not associated with the longline fishery. Rather, they are attributable to increases in the number of trolling vessels and to some extent to larger landings of the pole-and-line and handline fishing vessels.

Most Hawaiian longliners use a scaled-down version of the Japanese gear, the basic unit of which is a basket. The mainline, which has five to seven branch lines or droppers, extends from about 0.25 to 0.36 km. A vessel may connect up to 70 baskets in one set. Recently built longliners in the Hawaiian fleet have shifted from baskets to the more efficient tub gear, which has a continuous mainline that extends on some vessels for over 50 km.

There are 14 longliners operating full time in the Hawaiian fishery at the present time. These vessels are mostly of wooden construction, but in recent years, new, steel-hulled vessels have joined the fleet. Hawaiian longliners range in size from 13 to 24 m in registered length and vary from 36 to 161 GT (gross tons). The smaller vessels may carry a crew of three to five men, but the newer, long-range vessels can carry as many as nine men on trips which may last up to 3 wk.

One of the most recent and possibly the most successful new fishery to develop in Hawaii is the troll fishery for albacore. Based on background information gathered through research done by the Honolulu and La Jolla Laboratories of the National Marine Fisheries Service on albacore movement in the North Pacific, a mid-Pacific albacore trolling project was initiated in 1975 to fish in the immediate vicinity of the Emperor Seamounts which are located 1,500 km northwest of Midway Islands near lat. 34° - 36° N and long. 171° E. The information developed indicated that this area has considerable potential for an albacore surface fishery by trolling and possibly by pole-and-line methods during the summer.

When preliminary trolling results indicated that albacore, ranging from 3 to 16 kg, could be caught at rates as high as 500 per day, the State of Hawaii moved aggressively to obtain permission from the U.S. Navy to use Midway Islands as a refueling and transshipping base for the trollers. In 1979, 26 trollers ranging in size from about 18 to 21 m operated in this fishery. By fishing in the mid-Pacific from April, these trollers which traditionally fish the albacore grounds off the U.S. west coast from June or July through September or October extended their fishing time perhaps 2-3 mo (Altonn 1979; Cooke 1979).

The success of the albacore troll fishery is reflected in the landings. Whereas the annual landings of albacore mainly by the longline fishery around Hawaii in 1961-77 varied between 3 and 43 MT (average, 13 MT), the 1978 landing surpassed all previous landings, reaching 315 MT, of which 258 MT or 82% were landed by trollers fishing in the mid-Pacific. Early preliminary estimates place the 1979 landing at an astonishing 2,000 MT (Altonn 1979).

The Inshore Fishery

Around the Hawaiian Archipelago, the nearshore shelf zone unlike that supporting most of the world's great fishing areas is narrow and poorly developed, a condition which holds true for many oceanic islands in the central and western Pacific. The result is that only about 60 of the more than 680 species of fish, mostly found on the reef and over the narrow shelf slope zone, are commercially exploited. They are captured by a wide variety of gear including bottom line, handline, pole and line, bag net or purse seine, haul seine, pot, trap, anchored net, cast net, and gill net.

Of the inshore fish, the bigeye scad, Trachurops crumenophthalmus, is the most important followed by mackerel scad, Decapterus pinnulatus. The bigeye scad, second only to tunas and billfishes in total landings, is caught by three types of gear--bag net, which accounts for about 66% of the landings, handline, which lands about 20%, and gill net, which contributes about 13% (Kazama 1977). The main gear for mackerel scad are the hoop net, which accounts for slightly more than half of the catch, and the handline, which produces about 45%.

Vessels engaged in inshore fishing vary widely in size and shape ranging from small, wooden, metal, or fiberglass boats used by the weekend fishermen and which may fish only for one species, to the more recently introduced multipurpose vessels that may participate in various fisheries. One particular multipurpose vessel presently operating in various Hawaiian fisheries has a fiberglass hull, a registered length of 18 m, and a displacement of about 72 GT. It can carry a crew of nine men, has a range of 7,400 km, and has capabilities for conducting purse

seining, pole-and-line fishing, longline fishing, trapping, trolling, and handlining. The afterdeck has six baitwells for carrying live bait or holding catches alive until they can be landed for the fresh fish market. There are also provisions for freezing or brine chilling the catch. Multipurpose vessels of this type have been instrumental in opening up the newly discovered fishing and trapping grounds in waters of the NWHI (Northwestern Hawaiian Islands).

The important Hawaiian bottom fish fishery, conducted both in shallow and deep water, concentrates mainly on fishes of the snapper-grouper complex including snappers such as Pristipomoides filamentosus, P. sieboldii, P. zonatus, Aprion virescens, Etelis carbunculus, E. marshi, Lutjanus kasmira, Aphareus furcatus, and A. rutilans, a grouper, Epinephelus quernus, goatfishes, Parupeneus spp. and Mulloidichthys spp., and jacks, Seriola spp., Caranx spp., C. speciosus, Alectis spp., and Carangoides spp.

In the trap fishery for spiny lobster, Panulirus marginatus, catches have increased significantly in recent years. The lobster fishery in Hawaii goes back to pre-World War II years when it was concentrated only in the major Hawaiian Islands and catches were relatively small, averaging 15.5 MT annually. Wartime restrictions led to closure of many of the lobster grounds. When fishing resumed, catches reached 14.2 MT in 1944, climbed to 20.6 MT in 1947, then declined steadily until 1967 after which they stabilized between 2.0 and 4.2 MT until 1976.

The discovery by the Honolulu Laboratory in 1976-77 of new lobster trapping grounds in the NWHI, particularly around Necker Island and Maro Reef, brought about a renewed interest in lobster fishing. Long-range vessels capable of operating 2-3 wk without refueling or reprovisioning began fishing in the remote NWHI in late 1976. In 1977, these vessels produced a record catch of 38.9 MT of spiny lobsters, almost all of which was caught in waters of the NWHI. The 1978 catch, however, declined drastically, reaching only 15.3 MT.

RECREATIONAL FISHERY

A prominent feature of Hawaiian fisheries is the recreational fishery, in which a wide variety of boats, ranging from small skiffs to large charter vessels are used. The vessels that supply charter services, totaling 102 in 1976, troll for pelagic fish such as billfishes, tunas, mahimahi, and wahoo (Cooper and Adams 1978²). There are also numerous weekend fishermen who operate small boats and troll for pelagic fishes or use a variety of other gear for inshore species. In 1976, there were 1,544 noncharter, recreational-commercial trollers in the State. These vessels are operated by individuals in nonfishing occupations and who may be licensed; therefore, they are considered part-time commercial fishermen.

A survey conducted from July 1958 to June 1961 estimated that there were 122,400 recreational fishermen in the State at that time, but this number has undoubtedly increased substantially with an increase in the

²Cooper, J. C., and M. F. Adams. 1978. Preliminary estimates of catch, sales, and revenue of game fish for the Fishery Conservation Zone around the main Hawaiian Islands, by types of troll and longline vessels and by species, 1976. Southwest Fisheries Center Admin. Rep. 24H, 1978, National Marine Fisheries Service, NOAA, Honolulu, Hawaii, 10 p.

population (Hoffman and Yamauchi 1973). At any rate, the survey showed that 68.1% of these recreational fishermen participated in saltwater shoreline fishing, 12.1% fished from boats, 10.2% were divers, and 9.6% were either freshwater fishermen or did not specify their preference in type of fishing.

FISH PROCESSING

Except for the tuna cannery operating in Honolulu, there are no other major fish processing plants in the Hawaiian Islands. Skipjack tuna caught in local waters are sold fresh, canned, cured, or sold as bait. By far, the largest proportion of the catch is canned and perhaps up to 1,600 MT sold fresh (Hawaii. State Center for Science Policy and Technology Assessment 1978). The market for cured fish and bait utilizes only very small amounts of skipjack tuna. Large tunas such as yellowfin tuna, bigeye tuna, and billfishes are sold fresh and surplus tunas are shipped to lucrative markets in the continental United States and Japan. Almost all other fish and shellfish landed in the Hawaiian Islands are sold fresh. The exceptions are bigeye scad and mackerel scad, some of which are cured, and the spiny lobster, which in addition to being sold live is processed as frozen tails. Hawaii's fish cake manufacturers who formerly used locally caught billfishes as the main ingredient have switched to imported Japanese surimi, which is a semiprocessed wet fish protein prepared from Alaska pollock, Theragra chalcogramma. Billfishes and scrap fish are also ground and mixed with surimi whenever they can be obtained inexpensively and in large enough quantities.

AQUACULTURE

The Hawaii Division of Fish and Game's Anuenue Fisheries Research Center, recognized as a world leader in the culture of Malaysian prawn, Macrobrachium rosenbergii, began research on prawn culture in 1965 (Fujimura and Okamoto 1970). During the period 1972-77, annual commercial production increased from 1.8 to 23.1 MT. In 1978, although the projection indicated a production of 80 MT, the final estimate appears to be closer to 50 MT (Hawaii. State Center for Science Policy and Technology Assessment 1978). The total area available for culture reached 36.4 ha in 1977 with a potential capacity for producing more than 90 MT ([Hawaii.] Department of Land and Natural Resources 1978).

Commercial pond production of catfish, Ictalurus punctatus, in Hawaii began in 1974 on a modest scale, but by 1977, 6.5 ha of ponds were in production, yielding 6,200 kg/ha/yr, a figure which is more than four times the 1,400 kg/ha/yr average attained by catfish producers in the continental United States. The higher production was attributed to Hawaii's warmer climate and year-round growing season (Hawaii. State Center for Science Policy and Technology Assessment 1978). Although final production figures are incomplete, the projected production for 1978 was 46 MT of catfish.

Hawaii has also embarked on development of a cultured oyster industry in recent years. Cultured oysters, including the Pacific oyster, Crassostrea gigas, the American oyster, C. virginica, and the flat oyster, Ostrea edulis, are already reaching consumers in Honolulu. Although production figures are not firm, the State's projection was a harvest of

about 45 MT in 1978. Private enterprises in the oyster producing business are pioneering the use of the sluice or raceway culture technique of setting the animals in trays and maintaining an intensive feeding schedule using algae which are produced in nearby ponds. Tests have shown that market-size oysters can be produced in 7-9 mo. Estimated production under this intensive culture system is 9.8 MT of oyster meat per algal production acre (equals 0.4 ha) per year (Hawaii. State Center for Science Policy and Technology Assessment 1978). One firm estimates that it will be producing 10 million oysters by 1981 (Dupont³).

IMPACT ON STATE AND LOCAL ECONOMIES

The value of the commercial fish catch in Hawaii remained relatively static from 1961 to 1970, never exceeding \$4.0 million annually. In 1971, the value rose 34% to about \$5.2 million, then showed a smaller 10% gain in 1972 to \$5.7 million. From 1973 to 1975 the values fluctuated between \$6.0 and \$7.0 million, then rose to \$8.9 million in 1976. The rise in value continued in 1977, up 16% to \$10.3 million and reached a record \$12.2 million in 1978 (see footnote 1).

The recreational fishery has had a very significant impact on Hawaii's economy. The total estimated annual expenditures of all recreational fishermen in the State reached \$16.1 million during the period July 1958 to June 1961 (Hoffman and Yamauchi 1973). These expenditures were in three categories: (1) transportation costs, (2) food, beverages,

³James Dupont, Kahuku Sea Food Plantation, Kahuku, HI 96731. Pers. commun. September 1979.

and additional on-site living expenses, and (3) cost of gear and auxiliary equipment necessary for actual fishing. The economic impact of these expenditures on the State, measured in terms of additional income generated for the local economies, was estimated to be \$11.5 million.

Although it would appear useful to compare the economic impact of recreational fishing with that of commercial fishing, no attempt at such a comparison has been made. The indications are, however, that recreational fishing provides significant benefits to Hawaii, far greater than that derived from commercial fishing.

It should be noted that in Hawaii a gray area exists between what constitutes recreational and commercial fishing and, therefore, the commercial catch may be undervalued. Recreational fishermen are not licensed by the State, because there is no provision in the regulations for doing so; therefore, they are not allowed to sell their catches. However, it has been noted that many recreational fishermen dispose of their catches through various retail outlets. The extent to which this violation occurs is unknown at the present time.

SUMMARY

Fishing in Hawaii dates back to the ancient Hawaiian civilization, which was intimately tied to the sea. Early Hawaiian fishing methods were gradually incorporated into new techniques introduced by immigrants. Some of these techniques still exist today.

The major offshore commercial fisheries in Hawaii are primarily for tunas and billfishes. Catches in the pole-and-line and longline fishery have not changed significantly over the years; however, changes have

occurred in vessel design and gear. A new and perhaps one of the most successful fishery to develop in Hawaii in recent years is the troll fishery for albacore in the mid-Pacific. This fishery has made a significant impact on the fisheries scene in Hawaii.

On inshore fishing, catches of bigeye scad, mackerel scad, and species comprising the snapper-grouper complex have not shown any notable trends. The major innovation among the inshore fleet appears in the use of multipurpose vessels that participate in several types of fishing. These vessels have been instrumental in the development of the fishery for spiny lobster in the NWHI.

An increasingly important feature of Hawaiian fisheries is recreational fishing in which millions of dollars are expended by fishing enthusiasts in pursuit of pelagic fishes such as tunas, billfishes, wahoo, and mahimahi. Economic studies indicated that recreational fishing provided important benefits to Hawaii's citizens, far greater than that derived from commercial fishing.

In fish processing, a large percentage of Hawaii's skipjack tuna and albacore catches are canned; however, about 1,600 MT of skipjack tuna, together with almost all other offshore and inshore fish, are marketed fresh. A limited amount of fish are cured or sold as bait.

Aquaculture has become an important industry in Hawaii and undoubtedly will have greater impact on the economy as production facilities and yield increase for Malaysian prawn, oysters, and channel catfish.

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NOV 5 1979

TO ALL BILLFISHERS:

This is a report of the biological and statistical aspects of the Twenty-first Hawaiian International Billfish Tournament (HIBT). For 18 of the 21-year history of HIBT the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service (NMFS) has sent observers to the tournaments to collect biological data on billfishes. Besides collecting data, the observers have organized workshops, presented seminars, put up exhibits, and made themselves generally available to answer questions about fishes. In recent years I have added to our activities the instant analysis of your reports at radio round-up time to give you the best-area-of-the-day bulletin immediately after each round-up. And as a wrap-up, I write this report.

This year my assistant was Bob Humphreys. Also participating in making scientific observations were Dr. Richard W. Brill, newly appointed Director of Science of the Pacific Gamefish Foundation, and Peter Saul, Recreational Fisheries Advisory Officer from New Zealand.

A lot of people supported us with their cooperation and assistance. Without that support we would not have been able to complete our work. I wish to acknowledge you, billfishers, for responding so conscientiously to all the round-up calls and for allowing us to examine your catch. Jim Sutherland, Chris Mason, and Petra Layman of headquarters helped us in many ways before, during, and after the tournament. At radio round-ups Phil and Beverly Parker and Carol Zuzak assisted us in keeping our records straight. Colleen Bryant and Shirley Eldridge provided data from the catch reports. At the pier, Jack Fischer's magic unfailingly caused to appear anything we needed. A sincere mahalo to all.

THE CATCH

A new tournament rule this year was that a fish had to be at least 100 lb (45.4 kg) to qualify for points. This rule virtually eliminated all shortbill spearfish, sailfish, and striped marlin from qualifying. In the last 10 years of HIBT, except for one striped marlin of 102 lb (46.3 kg), none of the catch of these species even came close to 100 lb.

This year's catch was 62 blue marlin and 7 ahi (yellowfin tuna). With 70 teams and 5 days of fishing in the tournament, an average of

5.1 boat-days was required to land each fish, the worst rate since 1969 (Table 1). Beginning in 1970 HIBT has been scheduled to coincide with the dark of the moon. Before that no attention was paid to moon phase in the scheduling. Note that since 1970 the catch rate has improved substantially (Table 1). Even though this year's rate is the worst in 10 years, it is better than 7 of the 8 previous years. Although the blue marlin catch this year was lower than usual (84% of the average for 1970-78), the low ahi catch was the major contributor to the low rate. This year's ahi catch was 21% of the 1970-78 average catch of ahi.

Weights of blue marlin caught ranged from 115 lb (52.1 kg) to 616 lb (279.4 kg) and averaged 209.7 lb (95.1 kg). The ahi weighed 113-229 lb (51.3-103.9 kg) and averaged 152.4 lb (69.1 kg).

FISHING AREAS

Within the designated fishing boundaries of HIBT are 26 arbitrarily defined areas (Figure 1). Ten of these areas attracted 97% of the fishing effort. Data analysis was limited to these 10 areas, each of which had over 100 boat-hours of fishing in it (Table 2). Area *Tango* was by far the most popular area with 397 boat-hours. Although *Uniform Bravo* ranked seventh in popularity, its strike rate of 0.19 strike per boat-hour was decidedly the best (Table 2). Areas with the next best strike rates ranked in order were *Lima*, *Mike*, *Victor*, *Tango*, and *Sierra* (Table 2 and Figure 1).

The average strike rate for all the areas was 0.12 strike per boat-hour. This is 60% of last year's overall rate of 0.20 strike per boat-hour. In fact, the strike rate for this year's best area was lower than last year's average rate.

Hawaiian International Billfish Tournament scores are not determined by the number of strikes obtained but by the number of pounds of fish landed. Perhaps the number of pounds of blue marlin per boat-hour is a more meaningful measure of how good an area was. Based on that measure, the best areas were *Victor*, *Mike*, *Uniform Bravo*, *Kilo*, and *Sierra* (Table 2).

Fish were caught from 13 areas. Table 3 lists the number of each species and the average weight caught from each area. The largest blue marlin was caught in *Victor* and the largest ahi in *Kilo*.

SEX

Of the 45 blue marlin examined 38 were males and 7 were females for a male:female ratio of 5.4:1. This is the second highest male:female ratio since 1962 and continues the history of the predominance

of male captures at HIBT (Table 4). Of the fish examined the largest male weighed 259 lb (117.5 kg); the smallest female weighed 305 lb (138.3 kg). This distinctive difference in sizes between sexes prompted a spectator at the pier to ask if blue marlin underwent a sex change. The answer is no. Small female blue marlin do exist. There are fish species which undergo a sex reversal, however. For example, all Hawaiian threadfin or moi, start their lives as males and later become females. Other species which exhibit sex reversal belong, for the most part, in the threadfin family or the sea bass family. One could say that this trait runs in the family.

STOMACH CONTENTS

Table 5 is a summary of our examinations of blue marlin stomachs. Only two specimens were examined the first day because of the breakdown of the forklift that transported fish to the examination table. As usual, tunas, particularly skipjack tuna, squid, opelu, and spiny puffer were the most frequently occurring items in the stomachs. Not so usual was the high frequency of goatfish. An interesting item in three of the stomachs was young swordfish. At a foot (30 cm) in length, they were the smallest I have seen in marlin stomachs. In fact, except for a 14-lb (6.4-kg) skipjack tuna, all of the items in the stomach were small.

In addition to food items seven fish had parasites in their stomachs. Five of them had flukes which are common in stomachs of pelagic fish. The other two had a threadworm and a tapeworm, which are parasites seldom seen in marlin stomachs.

TIME, TACKLE, TIDE, AND TAGGING

The best hour for catching blue marlin was 10-11 a.m. (Figure 2). Four of the 10 large blue marlin (greater than 300 lb or 136 kg), however, were caught between noon and 1 p.m.

Of the 62 blue marlin landed, 39 were caught on 24-kg test line and 23 on 36-kg test line. The average weight of fish caught on 24-kg test was 185.2 lb (84.0 kg); on 36-kg test the average weight was 251.4 lb (114.0 kg). Thirty percent of the fish caught on 36-kg test weighed greater than 300 lb (136 kg) while only 8% of the fish caught on 24-kg test weighed greater than 300 lb. For the benefit of those of you who think in terms of tournament points, the 24-kg line accounted for 10,931 points including one "largest fish of the day" bonus whereas the 36-kg line accounted for 6,282 points including bonuses for four "largest fish of the day" and the largest fish of the tournament.

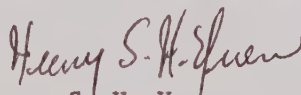
Forty-six of the blue marlin were caught on plastic lures, 10 on metal lures, 4 on live bait, and 2 on dead bait. Because we don't have data on how many plastic lures were trolled compared to metal lures or baits, I can't say whether plastic lures are preferred by blue marlin or by blue marlin fishermen.

The highest strike rates (strikes per boat-hour) for each day occurred on the rising tide (Figure 3). On Monday, Tuesday, Thursday, and Friday, the period just after low tide had the best strike rates. On Wednesday the period of best strike rate occurred just before high tide. On the other hand, the worst rates of the day occurred during periods of ebbing tide. On the one day (Monday) that the period of lowest strike rate was not during the ebbing tide, no part of the fishing day was in the ebb phase.

Except for inferences gleaned from Japanese longline fishery data, virtually nothing is known of the migratory routes of the billfishes which appear seasonally in Hawaiian waters. The tagging and releasing of fish can produce concrete evidence of their movements provided, of course, that the tagged fish are caught again and the tags are noticed and returned. This year with the lower weight limit of 100 lb (45.4 kg) in effect, HIBT promoted the tag and release of undersized billfish. Tagging equipment and supplies--tags, report cards, applicator tips, and pennants from NMFS and tagging poles from HIBT--were made available to every boat in the tournament. Although the actual tagging results during the tournament were meager--one shortbill spearfish tagged and released--I think that the tagging promotion did serve to increase your consciousness about tagging and its importance. Many of you have elected to retain the tagging equipment and supplies. I hope that your choosing to do so is a sign of your intention to tag fish in the very near future.

If you have any questions about this or any observations on game fishes you would like me to know about, please feel free to contact me.

Respectfully submitted,



Heeny S. H. Yuen
Leader, Recreational Fisheries

Attachments

October 22, 1979

Table 1.--Numbers of qualifying game fish landed and teams fishing during Hawaiian International Billfish Tournaments, 1962-79.

Year	Blue marlin	Black marlin	Striped marlin	Shortbill spearfish	Sailfish	Yellowfin tuna >100 lb	Total qualifying fish	Number of teams	Number of boat-days fishing ¹ per fish ¹
1962	30	1	--	--	1	19	51	68	6.7
1963	19	2	1	--	--	26	48	72	7.5
1964	31	--	1	--	--	2	34	69	10.1
1965	47	--	--	--	--	9	56	78	6.9
1966	26	3	2	--	--	7	38	72	9.5
1967	63	--	1	--	--	18	82	68	4.2
1968	36	2	4	--	--	4	46	85	9.2
1969	32	1	--	--	--	4	37	75	10.1
1970	91	--	2	--	2	14	109	73	3.3
1971	41	--	3	1	--	47	92	77	3.4
1972	77	--	--	--	--	11	88	59	3.4
1973	76	--	1	3	1	17	98	61	3.1
1974	66	2	1	6	--	37	110	64	2.9
1975	104	--	2	8	--	79	193	79	2.0
1976	47	1	3	5	--	32	88	74	4.2
1977	71	--	1	1	--	14	87	73	4.2
1978	105	--	2	9	--	43	159	65	2.0
1979 ²	62	--	--	--	--	7	69	70	5.1

¹Nine-hour fishing days, 1962-73; 8-hour days, 1974-79.

²Minimum size of 100 lb put into effect in 1979.

Table 2.--Strike and catch rates by area,
Hawaiian International Billfish Tournament, 1979.

Area	<u>Number of strikes</u> Boat-hour	<u>Number of</u> <u>blue marlin</u> Boat-hour	<u>Pounds of</u> <u>blue marlin</u> Boat-hour
<i>India</i>	0.08	0.027	5.0
<i>Juliett</i>	0.06	0.015	2.1
<i>Kilo</i>	0.09	0.031	6.2
<i>Lima</i>	0.15	0.026	5.4
<i>Mike</i>	0.14	0.029	8.3
<i>Sierra</i>	0.11	0.027	5.5
<i>Tango</i>	0.12	0.028	4.5
<i>Uniform Alpha</i>	0.09	0.015	2.8
<i>Uniform Bravo</i>	0.19	0.026	7.1
<i>Victor</i>	0.12	0.043	11.2

Table 3.--Number of fish caught by species, area, and date; Hawaiian International Billfish Tournament, 1979.

Date 1979	Area												
	H	I	J	K	L	M	N _B	R	S	T	U _A	U _B	V
Blue marlin													
August 20	--	1	--	2	2	2	--	1	2	2	1	1	1
21	1	2	--	3	--	--	--	--	2	--	--	2	1
22	--	2	1	1	3	--	--	--	--	2	1	--	1
23	--	2	1	--	1	1	--	--	2	4	--	2	2
24	--	--	--	$\frac{1}{7}$	$\frac{2}{8}$	--	$\frac{1}{1}$	--	$\frac{2}{8}$	$\frac{2}{10}$	$\frac{2}{4}$	--	--
Sum	$\frac{1}{1}$	$\frac{7}{7}$	$\frac{2}{2}$	$\frac{7}{7}$	$\frac{8}{8}$	$\frac{3}{3}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{8}{8}$	$\frac{10}{10}$	$\frac{4}{4}$	$\frac{5}{5}$	$\frac{5}{5}$
Average weight (lb)	462.0	188.1	137.5	197.1	206.8	287.7	129.0	165.0	199.8	178.6	178.3	271.8	260.4
Ahi													
August 21	--	--	--	1	--	--	--	--	--	1	--	--	--
23	--	--	--	--	--	1	--	--	--	--	2	--	--
24	$\frac{1}{1}$	--	--	--	--	$\frac{1}{2}$	--	--	--	--	--	--	--
Sum	$\frac{1}{1}$	--	--	$\frac{1}{1}$	--	$\frac{2}{2}$	--	--	--	$\frac{1}{1}$	$\frac{2}{2}$	--	--
Average weight (lb)	154.0			229.0		131.5				113.0	154.0		

Table 4.--Sex ratios for blue marlin examined from
Hawaiian International Billfish Tournaments, 1962-79.

Year	Number of males	Number of females	Ratio of Males to females
1962	16	7	2.3:1
1963	13	6	2.2:1
1964	14	12	1.2:1
1965	35	8	4.4:1
1966	16	8	2.0:1
1967	51	13	3.9:1
1968	24	10	2.4:1
1969	23	8	2.9:1
1970	63	14	4.5:1
1971	21	9	2.3:1
1972	64	8	8.0:1
1973	47	21	2.2:1
1974	46	14	3.3:1
1975	70	16	4.4:1
1976	7	37	0.2:1
1977	41	25	1.6:1
1978	80	22	3.6:1
1979	38	7	5.4:1

Table 5.--Stomach contents of blue marlin,
Hawaiian International Billfish Tournament, 1979.

	Date and number of stomachs containing listed items					Percent occurrence
	August					
FOOD ITEMS	20	21	22	23	24	
<u>Fish</u>						
Tunas, Scombridae	--	4	7	7	6	55.8
Skipjack tuna	--	4	5	5	4	41.9
Frigate tuna	--	--	2	1	2	11.6
Other tunas	--	3	3	5	1	27.9
Jacks, Carangidae						
Opelu	1	5	2	1	2	25.6
Akule	--	1	2	--	--	7.0
Spiny puffer, Diodontidae	--	3	3	--	6	27.9
Goatfish, Mullidae	--	1	3	3	2	20.9
Triggerfish, Balistidae	--	--	3	--	2	11.6
Squirrelfish, Holocentridae	--	1	2	2	--	11.6
Aweoweo, Priacanthidae	--	--	2	1	--	7.0
Snake mackerel, Gempylidae	--	1	1	--	1	7.0
Swordfish, Xiphiidae	--	1	2	--	--	7.0
Needlefish, Belonidae	--	--	2	--	--	4.7
Filefish, Monacanthidae	--	--	1	1	--	4.7
Cowfish, Ostraciidae	--	1	--	1	--	4.7
Puffer, Tetraodontidae	1	1	--	--	--	4.7
Lizardfish, Synodontidae	--	--	--	1	--	2.3
Flyingfish, Exocoetidae	--	--	--	1	--	2.3
Barracuda, Sphyraenidae	--	--	--	--	1	2.3
Mahimahi, Coryphaenidae	--	--	--	1	--	2.3
Bonnetmouth, Emmelichthyidae	--	--	--	1	--	2.3
Butterflyfish, Chaetodontidae	--	--	--	1	--	2.3
Unidentified fish	--	6	4	6	5	48.8
<u>Invertebrates</u>						
Squid, Decapoda	--	3	6	3	3	34.9
Crab, Decapoda	--	1	--	2	--	7.0
Octopus, Octopoda	--	1	--	1	--	4.7
Mantis shrimp, Stomatopoda	--	1	--	1	--	4.7
Unidentified crustacea	--	--	--	--	1	2.3

Table 5.--Continued.

	Date and number of stomachs containing listed items					Percent occurrence
	August					
DISORDERS	20	21	22	23	24	
<u>Parasites</u>						
Fluke, Trematoda	1	--	1	1	2	11.6
Threadworm, Nematoda	--	--	1	--	--	2.3
Tapeworm, Cestoidea	--	1	--	--	--	2.3
<u>Ulcers</u>	--	--	--	2	1	7.0
Empty or everted stomachs	1	1	1	2	--	11.6
Number of stomachs examined	2	10	11	12	8	
Total: 43						

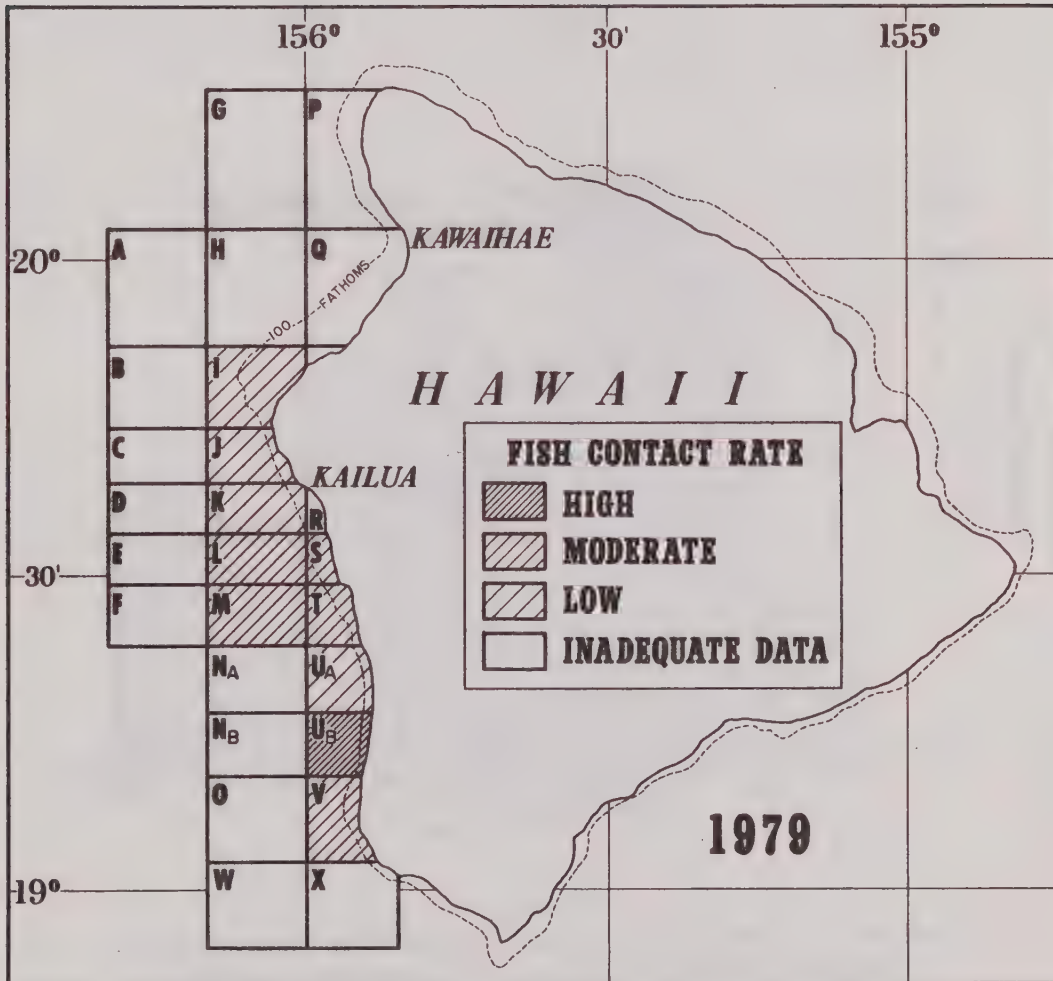


Figure 1.--Strike rate in various fishing areas.

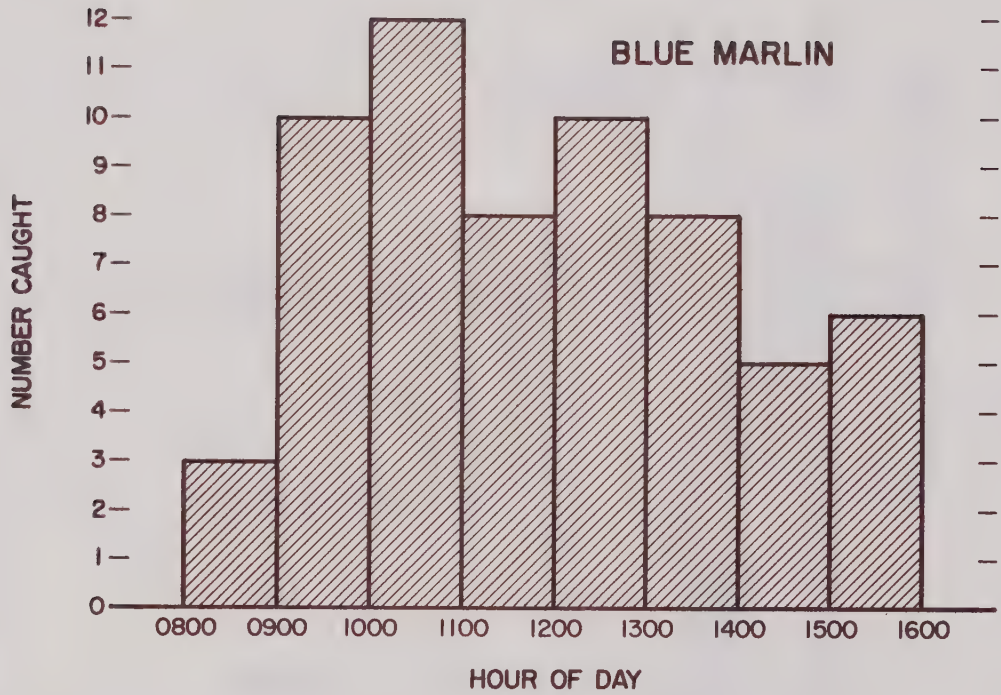


Figure 2.--Number of blue marlin caught by hour of day,
Hawaiian International Billfish Tournament, 1979.

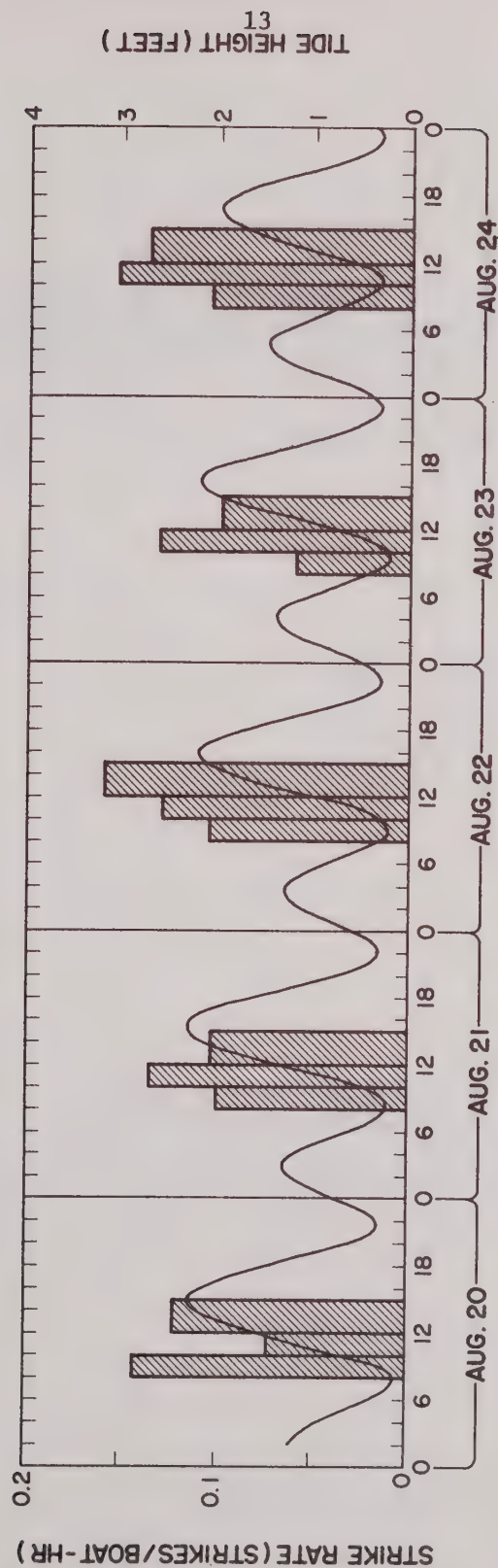


Figure 3.--Strike rates and tide cycle, Hawaiian International Billfish Tournament, 1979.

SUMMARY REPORT OF THE PLANNING WORKSHOP
FOR NATIONAL MARINE FISHERIES SERVICE RESEARCH
ON MARINE TURTLES IN THE CENTRAL AND WESTERN PACIFIC

Honolulu, Hawaii, 31 July-2 August 1979

NOV 1979

Richard S. Shomura (Chairman)
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
Honolulu, Hawaii 96812

October 1979

The "Planning Workshop for National Marine Fisheries Service Research on Marine Turtles in the Central and Western Pacific," sponsored by the National Marine Fisheries Service (NMFS), was held at the Honolulu Laboratory, Southwest Fisheries Center, on 31 July-2 August 1979 (Appendix 1, Workshop Agenda). Twenty persons attended from the continental United States, Hawaii, American Samoa, Guam, Palau, Federated States of Micronesia, and New Caledonia (Appendix 2). Honolulu Laboratory Director Richard S. Shomura was chairman of the workshop.

The purposes of the workshop were to review the status of knowledge on the turtle resources in the Hawaiian Archipelago and in areas of U.S. jurisdiction and interest in the central and western Pacific and to aid the development of a planning document which will identify long-term research needs, prescribe a time frame required to undertake this research, and establish priorities and estimate costs.

For purposes of clarity the proceedings of the workshop have been organized into four sections: (1) current turtle regulations and enforcement, (2) biology of Pacific turtle stocks, (3) stock assessment, and (4) recommendations for research.

Current Turtle Regulations and Enforcement

Current turtle regulations which appear in the Federal Register (vol. 43, No. 146, p. 32800-32811) were reviewed by representatives from the Western Pacific Program Office (WPPPO) of the Southwest Region, NMFS. The Endangered Species Act of 1973, as amended, prohibits import, export, take, interstate commerce, possession, and selling of hawksbill, leatherback, and Atlantic ridley turtles. Exceptions to the Act include the taking of turtles, by permit, for scientific purposes and to enhance propagation or survival, the taking of turtles as a result of economic hardship, and possession of turtles under grandfather clause. The penalties for violating these regulations are fines up to \$10,000 in a civil case and up to \$20,000 in a criminal case. Citizen suits may also enjoin persons who are allegedly violating provisions of the Act.

Changes in the Endangered Species Act of 1973 added three species to the endangered or threatened lists:

1. Green turtle
 - a. Florida and Mexico Pacific Coast - Endangered
 - b. All other populations - Threatened
2. Loggerhead turtle - Threatened
3. Pacific ridley turtle
 - a. Mexico Pacific Coast - Endangered
 - b. All others - Threatened

However, the Act allows the taking of these turtles by permits for scientific uses, to enhance propagation or survival, and for zoological and educational purposes. Taking of green turtles is permitted as incidental catches by fisheries and as subsistence catches in the Trust Territory of the Pacific Islands. Concerning mariculture products, regulations now in effect also

prohibit import of all marine turtles and marine turtle products. After 6 September 1979, further sales of turtle meat and products in interstate commerce will be strictly prohibited. However, because of the very large area--about 1.5 million square miles--enforcement in the Pacific is a problem of major proportion.

Current practices of the U.S. Customs Service were also discussed. In all areas under U.S. and quasi-U.S. jurisdiction, the laws state that there will be no taking of turtles, except in the Trust Territory where subsistence taking is allowed. Customs agents usually confiscate all turtle products that are declared at U.S. ports of entry. In order to retain turtle products, a citizen must be able to prove possession of that article before the laws were enacted.

Legal aspects of turtle harvesting in Micronesia are extremely confusing at the present time. In large part this confusion results from the transitional political status of various entities in the Trust Territory of the Pacific Islands. There are, however, provisions in Title 45, Section 2 of the Trust Territory Code, that prohibit the take of hawksbills less than 68.6 cm (27 in.) long, green turtles less than 86.4 cm (34 in.) long, and any turtles nesting during the periods 1 June-31 August and 1 December-31 January.

In American Samoa, there is no active enforcement of the Endangered Species Act. The primary reasons appear to be a lack of manpower to enforce the Act and lack of awareness of the threatened and endangered status of the marine turtles found in the area. There are no traditional native laws currently in effect which cover turtle conservation. It was noted, on the other hand, that in Western Samoa strong traditional tribal laws governing the conservation of endangered marine resources exist and are enforced.

In summarizing the enforcement difficulties, it was noted that these included the presence of many islands spread over a wide geographical expanse of the Pacific, lack of enforcement personnel, lack of public awareness of the provisions of the Endangered Species Act, and less than vigorous enforcement of existing regulations by the courts. To enhance public awareness, one suggestion was made to develop a brochure which would describe the turtles and the existing regulations. The brochure would be similar to that developed by WPPO to cover the humpback whales in Hawaiian waters. The workshop participants also compiled a list of recommendations relating to regulations, enforcement, and protection of marine turtles in the Pacific islands of U.S. interest (Appendix 3).

Biology of Pacific Turtle Stocks

The discussion on marine turtle resources of the Hawaiian Archipelago included a presentation of a slide show based on a draft report (Balazs, G. H. Synopsis of biological data on marine turtles in the Hawaiian Islands. Being prepared under a NMFS contract No. 79-ABA-02422). The report was not available for distribution at the workshop but will be distributed to workshop participants at a later date. The report covers life history aspects of the green turtle, Chelonia mydas, hawksbill turtle, Eretmochelys imbricata, and leatherback turtle, Dermochelys coriacea, and touches on two uncommon visitors to the Hawaiian Islands, the loggerhead turtle, Caretta caretta, and olive

ridley turtle, Lepidochelys olivacea. The report lists 669 references. Data from unpublished original research conducted by the author (George H. Balazs) are also included. Green turtles are the most abundant of the marine turtles found in Hawaiian waters. Based on available data, it appears that the Hawaiian Chelonia population probably represents an isolated breeding stock.

Briefly, the Hawaiian Chelonia population has not been given nomenclatural recognition. Characters that tend to distinguish them from other Chelonia populations include differences in coloration, steep-sided appearance of the carapace, indentations, or constrictions of the marginals over the hind flippers, and a unique land-basking behavior. Movement of the Hawaiian Chelonia has been studied through tagging. Of the various tags used, only one, Inconel 625 alloy tag, size 681, has been found to be corrosion-resistant in Hawaiian waters. Other identification techniques, such as production of antibodies, epoxy paint, tattoo, carapace notch, vinyl strip attached to the carapace, and plastic tags, have not proved to be satisfactory.

Green turtles occur only at select locations throughout the Hawaiian Archipelago. French Frigate Shoals in the Northwestern Hawaiian Islands has the largest breeding colony. Small groups and separately nesting individuals occur at Laysan, Lisianski, Pearl and Hermes Reef, Midway, and Kure. A resident non-breeding aggregation also occurs at Necker. The principal food source for Hawaiian Chelonia is marine benthic algae in shallow waters.

Hatchlings emerge from their nests in mid-July and early August. From French Frigate Shoals, an estimated 25,000 to 50,000 hatchlings are produced each year. Following a rapid departure from the adjacent waters, the hatchlings are "lost" to human contact and are not seen until they grow into juveniles larger than 35 cm (14 in.) in carapace length,

Based on limited tagging data, there appear to be significant individual differences in rate of growth and hence in age at maturity. Estimates for a 35-cm juvenile to reach a mean size of an adult female range from 11 to 59 yr. Several participants found this wide range difficult to accept and urged research be undertaken on this problem. Observations at French Frigate Shoals indicate that seabirds do not prey on hatchlings. On the other hand, tiger shark, Galeocerdo cuvieri, appears to be a more serious predator on marine turtles. Many carapace parts and bones have been found in stomachs of tiger sharks. Furthermore, it was noted that adult turtles frequently have flippers missing which is presumed to result from shark attacks.

Only a few hawksbill have been observed in Hawaiian waters. This species appears to concentrate along the Ka'u and Puna coasts of the island of Hawaii. Six nestings in 4 yr have been observed along these coasts. Hatchlings have been seen in waters around Oahu.

Sightings of leatherback turtles have been reported in sufficient numbers to indicate that this species is not an occasional visitor to Hawaiian waters. Loggerhead and olive ridley turtles, however, appear only rarely and their occurrence probably results from weakened individuals being swept into Hawaiian waters by the prevailing currents.

Discussion on turtles in other areas brought out that the hawksbill turtle nests all over the tropical Pacific, whereas the Kemp's ridley turtle has been observed to nest only on beaches in Mexico. It was also emphasized that in the central and western Pacific the green turtle populations appear to be small and scattered.

One of the most glaring gaps in our knowledge of the life history of green turtles is that of age at maturity and sexual or reproductive longevity. Even the data collected on Hawaiian Chelonia seem to indicate a considerable variability in the age at maturity.

It was noted that before the depletion of the stocks in Florida waters, juvenile green turtles about the size of "saucers" and "dinner plates" were quite common. Chelonia of similar sizes have only rarely been observed in Hawaii. Speculation about feeding behavior of juveniles brought out that they may be feeding in pelagic waters where "shears" occur, that is, in areas where sharp temperature discontinuities occur. These discontinuities often result in accumulation of living and non-living material along the shear line.

The situation in other Pacific island areas are briefly summarized below.

Kosrae has no record of nesting sea turtles. At Ponape, nesting of green turtles has been observed at Oroluk, Pakin and Ant Atolls, and on some of the reef islands. Truk does not appear to have sea turtle populations of critical importance. Isolated nesting of green turtles occurs at East Fayu and on the flat coral islands. In Palau, green turtles are moderately abundant and hawksbills are abundant.

The results of an aerial turtle survey around Guam in 1975-79 indicated that positive species identification of turtles from a moving aircraft is difficult; however, it is generally believed that green turtles were most prevalent in Guamanian waters. Western Samoa has a program for raising sea turtles wherein hatchlings are kept in ponds, marked, and released after 4-6 mo.

Rose Atoll, under the jurisdiction of American Samoa, has been set aside as a wildlife refuge and landing on the atoll is strictly prohibited, except by permission. This is the only known breeding area for the green turtle in American Samoa; however, virtually nothing is known about the colony. Hawksbills are also believed to nest at this location.

Around the other small, outlying atolls and islands under U.S. jurisdiction, green turtles occur in waters around Johnston Island, which is about 720 nmi southwest of Honolulu. There are also reported sightings of green turtles from Palmyra Island but no evidence of any nesting. There are, however, some sand beaches that may be used for nesting. Kingman Reef contains one small islet but it is not known if nesting takes place there. Howland, Baker, and Jarvis Islands are part of a National Wildlife Refuge; there is no information on occurrence of nesting at these islands. Green turtles have been observed at Wake Island but nesting has never been documented. For those islands outside U.S. control such as Christmas and Malden Islands, information is insufficient; however, green and hawksbill turtles have been reported to nest occasionally at Christmas.

The discussion then turned to the stock of turtles at the Galápagos Islands. About 99% of the turtles occurring there are green turtles and the remaining 1%, hawksbill turtles. The green turtle is widespread, nests on most of the beaches, and shows rather strong, seasonal nesting which begins in January and is completed by March. Several thousand turtles have been tagged to study their movement. Information on feeding pastures, however, are insufficient at the present time.

The Galapagos green turtles are morphologically rather small and are heavily pigmented. The pigments run to either black or yellow; the yellow variety is probably a genetic offshoot. Yellow pigmented turtles never mature sexually and are invariably obese. The Galapagos green turtles lay about 70-80 eggs per clutch.

The workshop participants then touched on turtles of Papua New Guinea. Both green and hawksbill turtles occur around Papua New Guinea and the stocks apparently are in good condition because of the rigidly enforced conservation policies. Green turtles nest along black sand beaches in Papua New Guinea.

The leatherback turtle is the third most important species in Papua New Guinea waters. This species has been observed to nest on black sand beaches. The Pacific olive ridley also occurs in Papua New Guinea and has been observed to be relatively abundant on the island of New Britain; however, there are no extensive nesting grounds for this species in this particular part of the world. The loggerhead turtle, a temperate water species, is an occasional visitor to Papua New Guinea. Of interest is the recovery of a tagged Australian loggerhead turtle which was recovered in Papua New Guinea. The flatback, Chelonia depressa, and the black-pigmented variety of green turtle are also found in Papua New Guinea waters.

Among South Pacific Commission (SPC) island states, the green turtle occurs around the Cook Islands and New Hebrides; New Caledonia possibly has a large population. Among species present in this very vast area of the South Pacific are the hawksbill, loggerhead, and green turtles; however, there is insufficient documentation of the occurrence of the leatherback turtle. The South Pacific Islands Fishery Development Agency (SPIFDA) has done some work on turtles but the project was terminated in 1973. Recent research among SPC countries involves turtle mariculture, especially in the Cook and Fiji Islands.

Five useful references on marine turtles in the Pacific are listed in Appendix 4.

Stock Assessment

Much of what was discussed previously was summarized to get a better perspective on how to plan for research on stock structure of marine turtles. Turtles evidently are long-lived, somewhat similar to cetaceans. There is definitely a need to initiate a population count in order to do any kind of stock assessment work, an urgent need to be able to age turtles accurately, to find out where turtles reproduce, and to examine the mechanisms that regulate populations. Tagging programs are definitely needed. The relative abundance and socio-economic importance of some of the major species of marine turtles in the central and western Pacific were summarized (Table 1).

Table 1.--Relative abundance and socio-economic importance of marine turtles in various U.S. territories and possessions and associated island groups in the central and western Pacific Ocean.

Area	Relative abundance ¹					Socio-economic importance ²
	Green turtle	Hawksbill turtle	Leatherback turtle	Olive ridley	Other species	
Hawaii	A	L	L	--	Loggerhead is stray	1.00
American Samoa	M	A	?	?	?	2.00
Guam	A	L	?	?	?	2.00
Northern Mariana Islands	--	--	--	--	--	--
Palau	M	A	?	?	?	2.50
Federated States of Micronesia	A	L	L	stray	--	3.00
Marshall Islands	A	M (prob.)	--	--	--	2.75

¹A = Abundant

M = Moderate

L = Low

(?) = Not seen

-- = No data

²3.00 = High

2.00 = Medium

1.00 = Low

Recommendations for Research

The following actions were highly recommended by the workshop participants:

1. Continuation of the in-depth study currently being conducted on the Hawaiian Chelonia and other marine turtles in the Hawaiian Archipelago as the results obtained from this research will most likely have wide application to other stocks of marine turtles throughout the central and western Pacific.
2. A "first-look" survey of the 20 green turtle nesting areas (Table 2) to determine the number of females using these nesting sites. The "first-look" survey should include an on-site survey and/or aerial reconnaissance over the nesting grounds. Islands best approached by land are Yap and Ponape (outer islands), whereas those more practically surveyed by air include islands in the Marshalls.
3. Time, personnel, and fund permitting, intensive studies to (a) evaluate hatching rate, localities of feeding pastures for adults, juveniles, and hatchlings, (b) determine reproductive potential of a given population, (c) collect and analyze life history statistics, and (d) conduct experiments to acquire knowledge on the behavior and physiology of marine turtles.
4. High priority be given to a tagging program to study turtle movement and problems of tag shedding and corrosion also be addressed. Tagging should be conducted not only among adult turtles but also hatchlings to determine their movements.
5. The determination of the "critical habitat" of the various species of marine turtles.
6. Aging of turtles should be given high priority. Without data on the age structure of a population, estimates of stock size cannot be derived with much confidence.
7. On-site surveys for one night to find out which species are nesting and to determine where they go. Surveys that run for 1 mo should provide more data on internesting period, whereas a 3-mo survey should reveal how many times turtles are coming back to nest.
8. Tracking of nesting females be given high priority. Research in this area will provide answers to short- and long-term movements of turtles. Information thus gained will aid in management of the stocks; e.g., knowledge of behavior and movement of green turtles during multiple nesting periods is needed for identification of "critical" habitat.
9. An agency be established to serve as a coordinating body and to be a depository for biological data and observations.

Table 2.--Nesting and feeding areas for green and hawksbill turtles
in the central and western Pacific Ocean.

Area	Nesting area		Feeding area	
	Green turtle	Hawksbill turtle	Green turtle	Hawksbill turtle
Hawaii	X	--	X	--
Palau				
Helen's Reef	X	--	--	--
Merir	X	--	--	--
Pulo Anna	X	--	--	--
Seventy Islands	--	X	--	--
West Barrier Reef	--	--	--	X
Ngeruangel	X	X	--	--
Yap				
Ulithi	X	--	--	--
Gaferut	X	--	--	--
Olimarao	X	--	--	--
West Fayu	X	--	--	--
Pikelot	X	--	--	--
Ngulu	X	--	--	--
Truk	--	X	--	--
Ponape				
Oroluk	X	--	--	--
American Samoa				
Swains	X	--	--	--
Rose Atoll	X	X	--	--
Marshalls				
Ujelang	X	--	--	--
Jemo	X	--	--	--
Bikar	X	--	--	--
Bikini	X	--	--	--

Appendix 1



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

31 July 1979

Planning Workshop for NMFS Research on Marine Sea Turtles
in the Central and Western Pacific

31 July-2 August 1979
Honolulu Laboratory Room 120

Agenda

1. Opening Remarks. (R. Shomura)
2. Review of Current Turtle Regulations in U.S.A. (R. Iversen)
3. Marine Turtle Resources of Hawaiian Archipelago. (G. Balazs, others)
4. Marine Turtle Resources of Other Pacific Island Areas. (M. McCoy, P. Pritchard, H. Hirth, G. Balazs, Fisheries Officers)
5. General Review and Comments of Green Sea Turtles. (A. Carr)
6. Discussion of Research Planning Document. (R. Shomura)
7. Discussions of Specific Topics--
 - a) Long-Term Objectives;
 - b) Stock Assessment;
 - c) Life History;
 - d) Socio-Economic.
8. Summary.
9. Closing Remarks. (R. Shomura)

Appendix 2



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
 NATIONAL MARINE FISHERIES SERVICE
 Southwest Fisheries Center
 Honolulu Laboratory
 P. O. Box 3830
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31 July 1979

Planning Workshop for NMFS Research on Marine Sea Turtles
 in the Central and Western Pacific

31 July-2 August 1979
 Honolulu Laboratory Room 120

List of Participants

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Serge Birk	Marine Resources Division, Palau
Archie Carr	University of Florida
Rene Grandperrin	South Pacific Commission, Noumea
Harold F. Hirth	University of Utah
Robert T. B. Iversen	Western Pacific Program Office, Southwest Region, National Marine Fisheries Service, Honolulu
Harry Kami	Government of Guam
Ernest Kosaka	U.S. Fish and Wildlife Service, Honolulu
Mike A. McCoy	Micronesian Maritime Authority, Ponape
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Jeffrey Polovina	Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service
Peter C. H. Pritchard	Florida Audubon Society/Southeast Region Sea Turtle Recovery Team
Richard S. Shomura	Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service
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Howard O. Yoshida	Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service

Appendix 3

Recommendations on regulations, enforcement, and protection for marine turtles in the Pacific islands of U.S. interest.

Area	Recommendations	Remarks
Palau	1. Scientifically supervised pilot headstarting program for hawksbills. 2. Protection of green turtle at Helen Reef and Merir. Tagging of same. 3. Stop sales of hawksbills to tourists.	Personnel changes (McVey, Owens).
Yap	1. Reinforce traditional restraints. 2. Grant "cultural variances" for subsistence use. 3. Avoid use of Yap outer island turtles by others (including Trukese).	Traditional restraints still strong. Provided for in 1978 regulations. Pikelot turtles still exploited by Trukese. Intense Pikelot tagging might temper situation; or might start civil war.
Guam and Northern Marianas	1. Endangered Species Act be enforced.	
Truk	1. Cessation of capture and sale of hawksbills. 2. Institute field studies and tagging.	Capture continuing; level uncertain. Not yet begun. No plans.
Ponape	1. Enforce U.S. law protecting hawksbills. 2. Declare Oroluk turtle sanctuary.	Law being enforced, but not in outer islands or outer villages. No action. Resident human population becoming permanent.
Marshalls	1. Strict enforcement of U.S. and Trust Territory of the Pacific Islands' law. 2. Conduct tagging or beach patrols to provide population estimates.	Main turtle islands controlled by one man or family.

Appendix 4

Background and Working Papers

Balazs, G. H.

1979. Synopsis of biological data on green turtle in the Hawaiian Islands. Final report, prepared for Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812, 180 p., September 1979.

Hirth, H. F.

1971. Synopsis of biological data on the green turtle Chelonia mydas (Linnaeus) 1758. FAO Fish. Synop. 85:1:1-8:19.

Molina, M. E.

1979. Summary of marine turtle sightings made on aerial fishery surveys during fiscal years '75 through '79. Division of Aquatic and Wildlife Resources, Department of Agriculture, Government of Guam, Agana, Guam, 5 p. (mimeogr.).

Pritchard, P. C. H.

1977. Marine turtles of Micronesia. Chelonia Press, San Francisco, 83 p.

[U.S.] Federal Register.

1978. Listing and protecting loggerhead sea turtles as "Threatened Species" and populations of green and olive ridley sea turtles as threatened species of "Endangered Species." Federal Register, 43(146):32800-32811.

SYNOPSIS OF BIOLOGICAL DATA ON THE GREEN TURTLE
IN THE HAWAIIAN ISLANDS

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CONTRACT NO. 79-ABA-02422

Final Report
Prepared for
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Center Honolulu Laboratory
Honolulu, Hawaii 96812

September 1979

PREFACE

This synopsis was prepared by George H. Balazs, Hawaii Institute of Marine Biology, University of Hawaii under contract number 79-ABA-02422. The contract objective was to bring together all the biological information presently available on the population of the green turtle, Chelonia mydas, in the Hawaiian Archipelago to focus attention on future research needs on this species. Since the report was prepared under contract, the statements, findings, conclusions, and recommendations expressed and presented herein are those of the contractor and do not necessarily reflect the view of the National Marine Fisheries Service.

Richard S. Shomura
Director, Honolulu Laboratory
October 25, 1979

INTRODUCTION

The green turtle, *Chelonia mydas*, constitutes most of the marine turtles in the Hawaiian Islands and has been the recipient of nearly all research conducted to date within this region of the Pacific. Although significant advances have been made during recent years in the knowledge of Hawaiian *Chelonia*, important aspects of the turtle's natural history remain to be elucidated. The purpose of this synopsis is to bring together all of the biological information presently known on the population and, in doing so, focus attention on future research needs. The unique behavioral and population characteristics of Hawaiian *Chelonia* detailed in this synopsis will also serve to emphasize the excellent research opportunities for gaining information applicable to all green turtle populations. The information contained in this synopsis has been derived from a comprehensive review of the literature, and from unpublished original research conducted by the author.

The format used in this synopsis is patterned after the synopsis series on species and stocks issued by the Food and Agriculture Organization (FAO) of the United Nations. A synopsis of biological data dealing with the green turtle on a global basis was published in 1971 as part of this series (Hirth 265). The present synopsis complements and updates this earlier document, which dealt only in general terms with Hawaiian *Chelonia*. An additional feature of the present synopsis is the incorporation of an extensive list of references covering Hawaiian cultural and legendary aspects of marine turtles.

The two other species of marine turtles found in the Hawaiian Islands are the hawksbill, *Eretmochelys imbricata*, and the leatherback, *Dermochelys*

coriacea. The hawksbill is only known to occur in small numbers exclusively at the southeastern end of the Archipelago where a few nestings have been recorded in recent years on the islands of Molokai and Hawaii. The leather-back is regularly sighted in offshore waters of the Hawaiian Islands, but nesting is not known to take place. The loggerhead, *Caretta caretta*, and the olive ridley, *Lepidochelys olivacea*, have also been documented in Hawaiian waters, but only as rare visitors. All of the known literature relating to these four species in the Hawaiian Islands has been included in the bibliography of this synopsis.

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1. IDENTITY

1.1 Nomenclature and Taxonomy

The valid name for the green turtle is *Chelonia mydas* (Linnaeus) 1768, with the *mydas* complex consisting of a number of genetically isolated populations distributed worldwide in tropical and subtropical latitudes. Some of these populations have been assigned subspecific names on the basis of coloration, carapace morphology and geographical location; however, for the most part detailed taxonomic studies have not been carried out.

The Atlantic green turtle, *Chelonia mydas mydas* (Linnaeus) (type locality-Ascension Island) has a predominantly brown coloration to its dorsal surfaces, a white to light yellow plastron, and a carapace displaying a low profile, especially from the middle of the lateral laminae to the periphery. At the present time there is no clear distinction between *Chelonia mydas mydas* and green turtles of the major Caribbean breeding colony at Tortuguero, Costa Rica. However, Carr (151) has expressed confidence that small morphometric, behavioral and physiological differences exist and, once demonstrated, the name *Chelonia mydas viridis* (Schneider) will apply.

In the Eastern Pacific, *Chelonia mydas agassizi* Bocourt has been described from the coasts of Central and South America and the Galapagos Islands. This subspecies is characterized by a greenish-olive dorsal coloration with the carapace at times strongly marked with black. In contrast with *mydas*, the *agassizi* carapace is highly arched with indentations over the hind flippers. *Chelonia mydas carrinegra* Caldwell, the stock of turtles with heavy black

pigmentation described from the Gulf of California and Pacific coast of Baja California, is now considered by some authorities to be synonymous with *Chelonia mydas agassizi*.

• The Hawaiian *Chelonia* population has thus far not been given nomenclature recognition. Based on turtles observed at French Frigate Shoals and Pearl and Hermes Reef in the Northwestern Hawaiian Islands, Carr (150, 151) indicated that *carrinagra* or *agassizi* characteristics are present. Similar features have also been recorded by Amerson *et al.* (32) and Balazs (57, 62). In contrast, Caldwell (147) and Pritchard (418) could not distinguish the small number of Hawaiian specimens they observed from *mydas* stock. The presence and possible predominance of *mydas*-like stock in the Hawaiian Islands have also been suggested by Hirth and Carr (267). Based on zoogeographic considerations and unspecified data, Oliver and Shaw (379) thought that the Hawaiian population might represent the easternmost outpost of the Western Pacific green turtle, *Chelonia mydas japonica* (Thunberg).

Since 1972 the author has observed approximately 2000 naturally occurring Hawaiian *Chelonia* of nearly all sizes, including large samples of adult males and females at the breeding colony of French Frigate Shoals. A reference collection of color photographs including many tagged animals has been compiled along with these field observations. Findings to date show that the predominant carapace coloration of adult females is heavy black with infusions of yellowish gold and olive. In most cases the black component comprises an estimated 80% or more of the carapace area. The head and dorsal surfaces of the flippers are also mainly black with light seams frequently outlining the scales on each side of the head. Along with these predominantly black turtles, a small number (<3%) of

adult females possess a basically brown colored carapace with patterns of yellow, gold and reddish brown. The head and dorsal surfaces of the flippers of these individuals are also lighter colored.

Within the adult females of the Hawaiian population there is generally a highly arched appearance to the carapace. The measurement of this characteristic has been undertaken by calculating the ratio of the curved and straight carapace widths as an estimate of carapace height. Although this ratio would not be valid for comparisons between radically different carapace shapes of the same straight width (i.e. domed vs a flat top), it nevertheless represents a simplified index of some value. In a sample of 93 females from French Frigate Shoals, this ratio was found to be $1.28 \pm .05$ with a range of 1.17-1.44. Similar measurements will be necessary in other *Chelonia* populations in order to determine if significant differences do indeed exist.

The carapace of the adult male in the Hawaiian population can also contain considerable black pigmentation, however greater variability has been recorded. Olive and yellowish gold components consisting of several different patterns can at times prevail. In general, the head and dorsal surfaces of the flippers are similar in pigmentation to the black-phase female. The male's carapace seems to present a lower profile than the female, however further morphometric data need to be gathered to clarify this apparent sexual dimorphism that was also a part of Caldwell's (147) description of *carrinegra*.

Plastron coloration in the adults of both sexes ranges from orange to yellowish orange. This color also encompasses the ventral surfaces of the marginals and the inframarginals, which are clearly visible during periods of land basking and nesting. A border of orange or yellowish orange often extends along the anterior edges of the second, third and forth marginals on both sides

of the carapace. The black or gray pigmentation in the plastron described for *carrinegra* by Caldwell (147) has only been found in a few of the adult Hawaiian *Chelonia* thus far examined by the author. A photograph showing the distinctly black pigmented plastron of an adult at French Frigate Shoals appears in a 1954 article by Eagle (204).

Indentations or constrictions of the marginals over the hind flippers have been found in varying degrees in Hawaiian *Chelonia* of both sexes. For the female, such a modification may serve to lessen the injury to dorsal surfaces of the hind flippers that can result from repeated contact with the marginals during excavation of the egg chamber.

Immature green turtles observed throughout the Hawaiian Archipelago have been found to show considerable variation in carapace coloration and pattern, both between and within different size categories. Colorations include combinations of yellowish gold, brown, reddish brown, black and olive. Like the adults, such colorations can only be properly described in conjunction with a dossier of color photographs. Preliminary evidence has been gathered indicating that some color phases, particularly those with black pigmentation, are more prevalent in certain resident foraging areas. This would suggest an environmental influence, resulting possibly from food sources or other characteristics of the habitat. Changes in the coloration of both the carapace and plastron have been recorded in Hawaiian *Chelonia* raised under captive conditions. For the plastron, extensive black pigmentation develops in juveniles by the time they reach 8 cm in straight carapace length, but fades and disappears by a size of approximately 20 cm. This has not been reported in other *Chelonia* populations and its adaptive significance is presently unknown. In addition to gradual and subtle transformations occurring during normal growth, some color changes recorded in captive

specimens have been both discrete and radical with the causative factor suspected to be of an environmental nature.

With respect to carapace morphology, the highly arched characteristic has not been found to manifest itself among immature Hawaiian *Chelonia* measuring less than approximately 65 cm in straight carapace length.

The overall question of taxonomic status for Hawaiian *Chelonia* is clearly a complex matter that may prove to be difficult to resolve solely on the basis of coloration and carapace morphology. The unique land basking behavior exhibited within the population could in fact be the most valid claim for eventual designation as a separate subspecies.

1.2 Common Names

Common names used for *Chelonia* in the Hawaiian Archipelago include green turtle, green sea turtle and honu (Hawaiian). Amerson *et al.* (32) have used the name "black turtle."

1.3 Size Categories

The size categories used for Hawaiian *Chelonia* are as follows:
hatchling - umbilical scar still present; juvenile - post-hatchling to 65 cm (25.5 in) straight carapace length; subadult - 65 cm to 81 cm (31.5 in) straight carapace length; adult - greater than 81 cm and reproductively mature.

These definitions are modified from the ones offered by Hirth (265) in that the division between juvenile and subadult categories is placed at 65 cm instead of 40 cm. This is justified on the basis that 65 cm is the minimum size at which sexual dimorphism (lengthening of the male's tail) has been observed to start taking place. Furthermore, human contact and research opportunities with

naturally occurring post-hatchling turtles less than 35 cm are extremely rare in the Hawaiian Archipelago. Retention of Hirth's (265) 40 cm division would consequently limit the juvenile category, for practical purposes, to a narrow 35-40 cm range.

1.4 Tagging and Measuring

The first recorded occurrence of *Chelonia* being "tagged" in the Hawaiian Archipelago involved the early 1900's cultural practice among some Japanese residents of inscribing characters on a carapace and returning the turtle to the sea (Cobb 176). The first known tags actually attached to Hawaiian green turtles occurred in June 1934 when brass tags inscribed with "U.S.S. ITASCA 1934" were placed on three adults prior to release at sea near Laysan Island (Baylis 104, Clapp and Wirtz 171). During short visits to Laysan Island and Pearl and Hermes Reef in June 1950, Brock (133) tagged an unknown number of green turtles using small stainless steel plates fastened to the carapace (Pacific Ocean Fisheries Investigations 387, R. Brock, personal communication, Anonymous 574).

The use of size 49 cattle ear tags manufactured from Monel 400 alloy by the National Band and Tag Company of Newport, Kentucky was initiated during the early 1960's by the Hawaii State Division of Fish and Game (Walker 532, 533, Woodside 554). This type of tag had already been successfully used on *Chelonia* in both Sarawak and Costa Rica. Personnel of the U. S. Fish and Wildlife Service and the Pacific Ocean Biological Survey Program (Smithsonian Institution) subsequently also used this tag on green turtles, as well as Hawaiian monk seals, *Monachus schauinslandi*, during intermittent survey and inspection visits to the Hawaiian Islands National Wildlife Refuge. In 1967 the U.S. Fish and Wildlife Service made these tags available to the Koral Kings Diving Club at the U. S. Navy Station on Midway for use on juvenile and subadult turtles captured during

recreational diving. By 1972 an approximate total of 800 turtles had been tagged as a result of these combined efforts. Nearly all of the taggings were in the Northwestern Hawaiian Islands, and the majority consisted of adults of both sexes captured while basking ashore (Amerson 30, Amerson *et al.* 32, Clapp and Wirtz 171, Clapp and Kridler 172, Ely and Clapp 211, Kridler 311-327, Olsen 380-385, Woodward 556).

Systematic tagging and monitoring of nesting green turtles at the French Frigate Shoals breeding colony was initiated by the author in June 1973. This research program has continued during subsequent years and has been expanded to include juveniles, subadults and adults basking ashore and residing in foraging areas throughout the Archipelago. Between 1973 and September 1976, size 49, as well as the smaller size 681, Monel tags were used in this program. Since that time only size 681 Inconel 625 alloy tags, specially manufactured by the National Band and Tag Company, have been used as the primary means of individual identification. These tags weigh 3.5 g and measure 8 mm by 29 mm. The change to Inconel was made following a determination by the author that considerable corrosion had occurred in many of the Monel tags placed on Hawaiian *Chelonia* (Balazs 66, Mrosovsky 363). The implications of this corrosion with respect to the introduction of heavy metals (copper and nickel) into an animal's system are potentially far reaching. Similar corrosion has been found in Monel tags used in a number of other marine turtle populations. No signs of corrosion have thus far been found in the Inconel tags placed on Hawaiian *Chelonia*.

The tagging sites used on Hawaiian *Chelonia* have been the trailing edges of the front flippers, both in the fold of flesh proximal to the body and between scales at a distal site. This latter location is more conducive to the visual recovery of tag numbers from basking turtles without causing disturbance.

When possible and appropriate, as many as three Inconel tags are placed at the different tagging sites on each turtle.

A number of other identification techniques have been tested for possible use in conjunction with the basic tag. This has included the production of identifiable antibodies (Benedict 107, 108, Hendrickson 262), epoxy paint applied to the carapace (Kridler 324, Anonymous 579), tattooing (Balazs 77), carapace notching of juveniles, vinyl strips attached through the carapace, and plastic tags manufactured by various companies. None of these techniques have proven to be very satisfactory for long-term identification.

Numbers formed on the carapace of nesting and basking turtles with aerosol paint (DuPont Lucite) have been successfully utilized for short term identification and monitoring of daily activities (Balazs 49, 51).

Under the present research program, a total of 1102 *Chelonia* has thus far been tagged throughout the Hawaiian Archipelago (Table 1). This includes 444 immature turtles and 140 adult males, two categories that are not normally tagged in most other marine turtle populations.

The measurements recorded for Hawaiian *Chelonia* have consisted of: straight and curved carapace length along the midline; straight and curved carapace width at the widest point (usually the sixth marginal); head width; straight plastron length along the midline; tail length from the posterior edge of the plastron along the midline; and body weight. Since June 1973, basking and nesting turtles have not been regularly turned over or otherwise restrained in order to carry out tagging and measuring. The suspension of this previous practice has lessened the opportunities to record plastron and tail measurements, body weight and, at times, other measurements. Nevertheless, this reduction of impact on turtles from research activities was deemed necessary in order to ensure the continuation of normal basking and nesting behavior (see Wallace 535).

2. DISTRIBUTION

2.1 Total Area

Green turtles are distributed at select locations throughout the 2,450 km long Hawaiian Archipelago. This nearly linear chain consists of 132 islands, islets and reefs extending from 18°54'N, 154°40'W to 28°15'N, 178°20'W in an isolated region of the North Central Pacific Ocean (Figure 1). Eight main and inhabited islands (Hawaii, Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai, Niihau) located in the southeastern segment of the Archipelago comprise over 99% or 16,650 km² of the total land area. The remainder consists of offshore islets and the small islands extending to the northwest of Kauai and Niihau known as the Leeward or Northwestern Hawaiian Islands. Except for Kure and Midway, the islands in this segment of the chain constitute the Hawaiian Islands National Wildlife Refuge.

There are 1,210 km of coastline in the Archipelago, with the main islands accounting for 1,165 km or 96% of the total. However, the adjacent underwater coastal shelf where most green turtles reside is generally very narrow with the 20 fathom curve (37 m) often only a few kilometers from shore. A number of large banks with little or no associated emergent land occur in the northwestern segment of the Archipelago. Within the 100 fathom curve (182 m), these submerged areas encompass approximately 16,000 km².

The closest island area to the Hawaiian Archipelago is Johnston Atoll located 820 km south of French Frigate Shoals at 16°45'N, 169°31'W. A green turtle aggregation of undetermined composition and size occurs at Johnston, however its relationship, if any, to Hawaiian *Chelonia* is not known at the present time. An isolated green turtle aggregation also occurs at Wake Island (19°18'N, 166°36'E), which is 1,550 km southwest of Midway and the closest island area

located to the west of the Hawaiian Archipelago. One of the juveniles tagged at Midway was subsequently recovered at Wake, however, the weakened and apparently pathological condition of the turtle suggests that it may have passively drifted there with prevailing winds and currents (Balazs 69, 81, Anonymous 641). Nevertheless, the relationship of the Wake aggregation remains to be determined.

The distribution of green turtles in the Hawaiian Archipelago has been reduced within historical times. A breeding colony that formerly occurred at Polihua Beach on the island of Lanai no longer exists (Balazs 55, Emory 213, Kahaulelio 281, Tabrah 473). Reductions have also occurred in the distribution of green turtles in their resident foraging areas adjacent to the main islands (Balazs 46, 48, Hendrickson 262, State of Hawaii 459-463). In the Northwestern Hawaiian Islands, the large aggregation of green turtles that formerly occurred at Laysan Island has nearly disappeared (Ely and Clapp 211). The aggregation at Pearl and Hermes Reef appears to be following a similar pattern and the situation at this location warrants attention.

2.2 Differential Distribution

2.21 Adults

The distribution of adult *Chelonia* in the Hawaiian Archipelago is determined primarily by the locations of acceptable breeding, feeding and resting habitat and, of course, the existence of sufficient numbers of animals to utilize such areas.

In excess of 90% of all breeding by Hawaiian *Chelonia* occurs at French Frigate Shoals (Figure 2), a 35 km long crescent-shaped atoll situated in the middle of the Archipelago (Amerson 30, Balazs 51, 55, 57, Hendrickson 262, Hirth 265, Kridler 311-327, Olsen 380-385). Small groups of turtles and separately nesting individuals using Laysan, Lisianski, and Pearl and Hermes Reef account

for the remaining reproductive effort. Only a few nestings have ever been recorded at Kure and Midway (Balazs 76).

Feeding and resting areas where adult Hawaiian *Chelonia* live the greater portion of their lives during nonbreeding periods are located in coastal waters of both the main islands and the Northwestern Hawaiian Islands. The principal food source, marine benthic algae of several genera, is restricted to shallow depths where sunlight, substrate and nutrients are conducive to plant growth. Feeding pastures used by adults are usually less than 10 m deep, and frequently not more than 3 m deep. The underwater sites where adults regularly retreat for periods of quiescence include coral recesses, the undersides of ledges, and sand bottom areas (called "nests") that are relatively free of strong currents and disturbance from natural predators and man. These resting areas for adults in the main islands usually occur at depths greater than 20 m, but probably not normally exceeding 50 m. Available information indicates that the resting areas are in proximity to the feeding pasture. Periods of rest near the feeding pasture are also known to take place while floating at the surface during light winds and calm seas. This surface basking undoubtedly yields a thermal advantage due to solar radiation directly on the carapace and the warmer layer of water present at the surface. In addition, less energy would be expended by not having to periodically swim to the surface for respiration.

Some of the important resident areas in the main islands where adult *Chelonia* feed and rest are shown in Figure 3 and include the following: Hawaii - Kau and North Kohala Districts; Maui - Hana District and Paia; Lanai - northern and northeastern coastal areas bordering the Kalohi and Auau Channels; Molokai - southern coastal areas from Kamalo to Halena; Oahu - Kailua and Kaneohe Bays, and northwestern coastal areas from Mokuleia to Kawaiiloa Beach; Kauai -

1
Princeville, northwestern coastal areas of Na Pali, and southern coastal areas from Kukuiula to Makahuena Point. Additional investigations are needed to adequately delineate these and other coastal areas.

In the Northwestern Hawaiian Islands, resident aggregations of adults are known to occur at Necker, French Frigate Shoals, Lisianski, Pearl and Hermes Reef and, to a lesser extent, Laysan, Midway and Kure. Except for Midway, resting habitat at these locations also includes shoreline areas where land basking regularly takes place. Although a few random sightings have been made, it is still unknown if adults, or any other size categories, reside on or in some way utilize the submerged banks with no emergent land located in the northwestern segment of the Archipelago. Data are also lacking for Nihoa and Gardner Pinnacles.

While in transit during reproductive migrations, adult Hawaiian *Chelonia* are distributed at unknown locations in the pelagic environment between the islands of the Archipelago.

2.22 Hatchlings, juveniles and subadults

Hatchlings emerge from their nests and enter the water at French Frigate Shoals and the other breeding sites in the Northwestern Hawaiian Islands between mid-July and early October. Following a rapid departure from the adjacent waters, they are lost to almost all human contact. This disappearance is consistent with what has been found to occur in other *Chelonia* populations (Hirth 265). Hawaiian green turtle hatchlings are thought to be subsequently dispersed in the pelagic environment by currents and vigorous swimming. Surface drift trajectories plotted for the theoretical movement of hatchlings leaving French Frigate Shoals suggest a predominant westerly dispersal (Figure 4). However, *Chelonia* hatchlings are strong swimmers and the distinct possibility exists that considerable movement takes place at variance with prevailing surface currents.

The 28 March 1779 log of the *Resolution* records the pelagic sighting of a post-hatchling turtle of unknown species to the southwest of the Hawaiian Archipelago at 20°15'N, 179°20'E (Beaglehole 105).

The distribution of juveniles up to 35 cm in the Hawaiian Archipelago is also unknown, due again to a nearly complete absence of human contact. Turtles of this size are almost certainly still residing in the pelagic environment where the chances of seeing them are greatly reduced. Nevertheless, predation by certain pelagic fishes such as the oceanic whitetip shark, *Carcharhinus longimanus*, could be expected to take place. Efforts are therefore being made to recover juveniles of this "lost" size from the stomachs of potential predators (Balazs 70, 79, Hendricks 261, Anonymous 658).

Juveniles larger than 35 cm as well as subadults can be found feeding and resting in coastal areas throughout the Archipelago. These turtles frequently reside in the same general area as the adults. There is, however, the tendency among juveniles and subadults to utilize resting habitat located at a shallower depth. In addition, only juveniles are able to use some feeding pastures due to the very shallow depths involved.

3. ECOLOGY AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Adult males of the Hawaiian *Chelonia* population have a 35 to 45 cm long prehensile tail that extends beyond the hind flippers while swimming and is larger in overall diameter than the tail of the adult female. The adult female's tail ranges from 20 to 25 cm in length and only extends to about the middle of the hind flippers. The single nail present on the foremargin of each

front flipper is also longer in the adult male. However, in both sexes this structure can be considerably worn down, probably due mostly to abrasion with hard substrate encountered while feeding and resting underwater. Furthermore, the nails on the female receive some wear during nesting, while nails on the male may be abraded during copulation. A heavily keratinized tip is present at the end of the male's tail, but this may be missing in many individuals due to injury from other turtles or predators.

It is presently only possible to determine sex on the basis of external characteristics in individuals larger than 65 cm. Even then, caution must be exercised in that lengthening of the tail in some males does not start until a greater size is reached.

3.12 Maturity

The smallest female thus far found nesting at French Frigate Shoals measured 81 cm in straight carapace length, with 92 cm being the overall mean (Table 2). Curved carapace measurements are presented in Table 3 for comparative purposes. Data by Kridler (311-327) and Olsen (380-385) show that the mean weight of adult females is 110 kg (range 68-148 kg N=69). As noted by Hirth (265), nesting aggregations of *Chelonia* may consist of some females that grew to a large size after reaching maturity, and some that did not mature until reaching a large size. Such a phenomenon could also be expected for adult males. It is presently not possible to identify newly matured individuals (recruits) in the French Frigate Shoals breeding assemblage, however continued tagging and collection of size frequency data may eventually provide the basis for this determination.

The age at which green turtles mature under natural conditions has received very little research attention in most populations, although estimates based principally on captive growth rates have appeared in the literature (Hirth 265). For Hawaiian *Chelonia*, tag and recapture experiments with wild juveniles

have demonstrated significant differences in the rates of growth, hence age at maturity, between resident areas throughout the Archipelago (Balazs 81). The projected lengths of time for 35 cm juveniles to reach the mean size of adult females range from 11 to 59 years (Table 4). Turtles that reside in the North-western Hawaiian Islands seem to require the longest periods of time to mature.

3.13 Mating

Courtship and copulation take place in the shallow waters of French Frigate Shoals, usually within two kilometers of the 11 small islands present at this location. Some observations have suggested that the greatest influx of males to the area occurs prior to the arrival of most females (Balazs 49, Olsen 382). This is complicated, however, by the presence of adult males that are known to reside for extended periods at French Frigate Shoals.

Copulation has been observed taking place at the surface, on the bottom, and at various depths within the water column. Several males are almost always in attendance with a copulating pair, circling, smelling and biting the tail and flippers of the successfully mounted male. The injuries inflicted by this behavior are frequently extensive with scales and flesh being torn away and the underlying limb bones exposed. Males that have undergone these assaults during previous seasons can often be recognized by the missing areas along the trailing edges of their front flippers and the presence of thick, nonpigmented scar tissue. These scars may eventually be useful in the identification of neophyte males at the breeding colony.

The male maintains his position during copulation by grasping the margins of the female's carapace with the distal areas of his four flippers. The nail on the front as well as the hind flippers seems to provide some

assistance to this effort. The muscular prehensile tail also serves as a holding device by extending under the female to a position where the penis can be inserted into the cloaca. During copulation the female is in complete control of all movement since her four flippers are not restrained. Copulating pairs still locked together have been observed both diurnally and nocturnally in water only several centimeters deep adjacent to the islands at French Frigate Shoals. This beaching maneuver is presumably carried out by the female in an attempt to detach the male.

Most copulation at French Frigate Shoals occurs during the early portion of the breeding season, between mid-April and early June. The use of identification numbers painted on the carapace of nesting turtles has indicated that females will not copulate after laying their first clutch of eggs. Copulations recorded later in the breeding season appear to involve females that have only recently arrived at French Frigate Shoals.

Copulating turtles have been seen at Lisianski during April 1976 (C. Fiscus, personal communication), and at Pearl and Hermes Reef during March 1961, late May 1967 (Amerson *et al.* 32) and April 1976 (DeLong *et al.* 195). No records exist for Laysan, Kure and Midway.

Two adult males locked together in a copulatory position have been observed on several occasions at French Frigate Shoals, both during the breeding season and in the month of December. During one of these encounters, the position was maintained for at least 20 minutes. Similar behavior among males has also been documented at Necker, a small rock island with no sand beaches located 155 km east of French Frigate Shoals (Balazs 72).

3.14 Fertilization

It is uncertain if the eggs of *Chelonia* (and other marine turtles) are fertilized as a result of copulation that occurs within the same breeding season, or from spermatozoa stored in the reproductive tract resulting from copulation during a previous season. If storage is a prerequisite for the fertilization,

and copulation only occurs near the nesting beaches, then the neophyte female would have to make her first visit to French Frigate Shoals solely for mating purposes. Such a trip could, however, also involve nesting excursions ashore, but with only infertile eggs or no eggs at all being laid. Although both of these occurrences have been documented at French Frigate Shoals, other factors could very well be responsible.

In an effort to determine if fertility decreases at French Frigate Shoals as the breeding season progresses, 40 precounted egg clutches laid over a 72 day period (June-August 1974) were excavated and examined following the natural emergence of hatchlings. Regression analysis of these data showed a tendency toward decreased fertility with time, however this was not found to be significant ($p=.08$).

3.15 Nesting and habitat characteristics

Nesting takes place at French Frigate Shoals only on the islands of East, Whale-Skate, Trig, Tern, Gin and Little Gin (Figure 2). Of the females present for each breeding season, approximately 55% nest on East and 35% nest on Whale-Skate. East Island has consequently been the site of intensive research during each breeding season since 1973 with surveys being made at regular intervals on the other islands. Nesting commences during the middle of May, reaches its peak during late June, and declines to a very low level by early August. Some sporadic nesting may occur until mid-September. Although actual egg deposition takes place at night, or at least by sunrise, females have been recorded ashore excavating a nest site as early as two hours prior to sunset.

East and Whale-Skate are the two largest naturally occurring islands at French Frigate Shoals, consisting of 4.0 ha and 6.8 ha, respectively, with

elevations not exceeding 2 m. Both islands have a calcareous substrate composed of fine to coarse fragments of corals, coralline algae, molluscs and barnacles. The interiors of both islands have low vegetation (*Tribulus*, *Chenopodium*, *Portulaca*, *Boerhavia*) and are rich with humus originating from nesting seabird colonies. From 1944 to 1952 East Island was the site of a 26 man U. S. Coast Guard navigation (LORAN) station. Although some clean-up activities took place in 1965 and 1973, remains of this abandoned facility are still prominent on the island. Tern Island, located 11 km to the northwest of East Island, is a reconstructed island that was enlarged by dredging and landfill from 4.5 ha to 23 ha for military purposes in 1942 (Amerson 30, Berger 125, Olsen 383). From 1952 to 1979 a U. S. Coast Guard LORAN station was also present on Tern Island.

Mean monthly sea surface temperatures recorded at French Frigate Shoals between 1974 and 1976 were found to range from 23.8°C to 28.3°C, with the warmest water generally occurring from June through October (Figure 5). This is similar to sea surface temperatures found in the main Hawaiian Islands. The mean annual rainfall at French Frigate Shoals is 115 cm with the driest months being April through November. Additional climatic data for the area are presented by Amerson (30).

Green turtles nesting at East Island have been recorded laying as many as six egg clutches within a season, however the mean number is only 1.8 (Table 5). Approximately 40% of the turtles lay only once in a season. Almost 10% make nesting attempts on several consecutive nights, but do not lay eggs and often are not seen again. Only a few turtles (<5%) have been recorded each season changing islands once nesting has started. This factor alone would therefore not fully explain the absence of oviposition by some individuals. It is plausible that some of these turtles are releasing their eggs in the water

due to a nesting dysfunction, while others could be mortalities due to predation by tiger sharks, *Galeocerdo cuvier*.

The length of time between oviposition in turtles that lay more than once in a season ranges from 11 to 18 days, with the mean being 13 days (Table 6). During this interesting interval, turtles identified by painted numbers are regularly seen basking at East Island and swimming in the adjacent waters. The undersides of reefs that extend both to the southeast and northwest of the island are also known to be utilized during the interesting period. In a preliminary experiment conducted during June 1979, the maximum diving depth recorded with small depth gauges attached to two females at Trig and Whale-Skate Islands was 12.8 m. This suggests that movement to deeper waters outside the lagoon may not be taking place during the breeding season.

The degree of site preference displayed by green turtles nesting at East Island within a season has been examined by dividing the shoreline into 17 50 m-long reference areas. Observations made over the 1973, 1974 and 1975 seasons revealed that 32% of the egg clutches laid during renestings were in the same 50 m area as earlier nestings. Approximately 60% were in the same or an adjacent 50 m area, while 83% of the turtles emerged on the same side of the island as the earlier nestings. Some individuals showed considerable site fixity, as demonstrated by two turtles in 1974 that each nested four times in the same 50 m area, and a turtle that nested six times, alternating regularly between the same two areas (1 and 6). Also during 1974 renestings by five turtles involved egg clutches that were laid only 1.5 m to 3.5 m from an earlier clutch.

The locations of 220 egg clutches laid at East Island during the 1974 season are presented in Figure 6. The unutilized portions of the interior of areas 2-3 and 14-16 contain several low concrete foundations from the abandoned

Coast Guard facility. Although suitable substrate for nesting is also present, very few turtles have ever been recorded entering this region of the island.

Usually less than half of the turtles that emerge for nesting on any one night successfully lay eggs (Figure 7). The remaining turtles continue to emerge on subsequent nights until oviposition is achieved or, as previously described, the turtle is no longer present. Many of these nesting attempts involve the nearly complete excavation of an egg chamber before abandonment takes place and another site is selected on the island. In other cases, only rudimentary body pits are dug before a site is abandoned. Three factors that contribute to the incomplete excavation of a nest include injuries or amputations of a turtle's hind flippers, insufficient moisture in the substrate due to low rainfall, and contact with buried antenna wire and other debris present on East Island. It is also possible that some of these nesting attempts are unsuccessful because the complement of eggs has not yet developed to a stage for oviposition to occur. The tendency of some green turtles to make short, nonegg laying emergences in which the tracks form a parabolic curve (Carr *et al.* 1953, Hirth 1965) has only rarely been recorded in Hawaiian *Chelonia*. The "sand-smelling" behavior exhibited by newly emerged females in some green turtle populations has never been observed at French Frigate Shoals.

During the nesting process, Hawaiian *Chelonia* are least susceptible to disturbance immediately following oviposition when nest covering has just started to take place. Carapace measurements and tagging are therefore usually carried out during this period.

A sample of 50 egg clutches counted during oviposition over a 75 day period (June - August 1974) at East Island revealed a mean of 104 eggs per clutch

with a range of 38 to 145 eggs. Multiple regression analysis of these data was conducted to determine if significant relationships exist between the number of eggs in a clutch and the independent variables of: time of oviposition within the season (x_1); ratio of the curved and straight carapace widths of the female (x_2); and straight carapace length of the female (x_3). Larger females were found to lay significantly ($p < .05$) more eggs per clutch. Although there was a tendency for fewer eggs per clutch to be laid as the season progresses, this was not significant ($p = .10$). The relationship between the curved-straight width ratio and number of eggs per clutch was also not found to be significant ($p = .30$). This suggests that body thickness alone is not an adaptation for the storage of greater numbers of eggs. The resulting formula for predicting the number of eggs in a clutch (y) is $y = -268.704 + (-0.271)x_1 + 93.768x_2 + 2.819x_3$.

The mean incubation period (days to hatchling emergence) of 38 nests laid at East Island from June to August 1974 was found to be 64.5 days with a range of 54 to 88 days. Multiple regression analysis of these data found no significant relationships between incubation period and time of oviposition within the season, coarseness of the nest substrate, or depth of the egg chamber. The mean egg chamber depth was 60 cm (range 48-74 cm). A significant relationship ($p < .05$) was found between depth of the egg chamber and coarseness of substrate, with shallower chambers being excavated in coarser substrate. No significant relationship was found between egg chamber depth and size of the nesting female.

The mean width and length of the surface area excavated by 19 turtles that successfully nested on East Island was 2.0 m (range 1.7-2.7 m) and 3.8 m (range 2.3-5.0 m), respectively. No significant relationship was found between these measurements and the size of the nesting female.

Turtles on both East and Whale-Skate Islands regularly come into contact with ten species of nesting seabirds, the most abundant of which are sooty terns (*Sterna fuscata*) and wedge-tailed shearwaters (*Puffinus pacificus*). The crushing of eggs and young chicks by nesting turtles consequently takes place to varying degrees depending on the time of the season. In addition, adult shearwaters occasionally become buried in their underground burrows as a result of turtle activity. Monk seals hauled out along the shoreline and in the vegetation zone are also encountered at times by nesting turtles, but usually little if any interaction takes place.

Table 7 presents the results of 40 precounted egg clutches laid at East Island from June to August 1974 that were excavated and examined following the natural emergence of hatchlings. Multiple regression analyses of these data were conducted to determine if significant relationships exist between 1) percent of eggs hatched, 2) percent hatchling emergence, 3) percent dead hatchlings, 4) percent partially developed but dead embryos, 5) percent of eggs with no apparent development, and the independent variables of 1) time of oviposition within the season, 2) coarseness of the nest substrate, 3) depth of nest, and 4) straight carapace length of the female. The only significant relationship ($p < .05$) found was that the percent of hatchlings emerging at the surface decreases in egg clutches that are laid as the season progresses.

3.16 Reproductive cycles

Reproductive cycles, as measured by remigration intervals, have been documented in 21 nesting females at East Island since June 1973 (Table 8). Fourteen of these turtles (66.7%) displayed a two-year cycle, six (28.6%) a three year cycle, and one turtle (4.7%) was not seen again until six years

after being tagged. Thus far, no nesting turtles have been recovered at French Frigate Shoals after only a one year absence. The present predominance in recordings of two year nesting cycles is due to the significant increase in recoveries made during the 1979 season of turtles tagged two years earlier in the 1977 season (Table 8). Because 1977 was the first season in which the more durable Inconel tags were used at French Frigate Shoals, continued monitoring and tagging will be necessary during future breeding seasons (particularly 1980 and 1981) in order to accurately determine the most common nesting cycle. In view of the long time periods apparently required for Hawaiian *Chelonia* to reach maturity at certain resident foraging areas (section 3.12), it is reasonable to assume that the same controlling ecological factors would also cause protracted periods for reproductive readiness to be reached between remigrations. The occurrence of some nesting cycles far greater than three or even six years should therefore be considered as a distinct possibility. Furthermore, the low recovery rates of tagged adult females in both the Hawaiian and Caribbean (Carr *et al.* 1953) *Chelonia* populations suggest the possibility that many turtles may only be involved in a single breeding season during the course of their entire lifetime.

The reproductive cycles of males at French Frigate Shoals have been documented in 16 cases. Nine of these (56.2%) represented a one year cycle, five (31.3%) a two year cycle, and two (12.5%) a three year cycle. The nature of these tag recoveries indicates that the one year cycles involve remigrations rather than simply a residency at French Frigate Shoals. The apparent predominance of a one year cycle in males may be due to a lower energy requirement for reaching reproductive readiness between remigrations in comparison to females. Although the occurrence of two and three year cycles is believed to be valid, it

should be noted that greater difficulties are encountered in reliably determining male reproductive cycles that are longer than one year. This is due to the fact that there is no assurance that all males will come ashore to bask during a given season and, therefore, be available for tagging and tag recovery.

The modulation of reproductive cycles (see Carr *et al.* 1953) has thus far been recorded in two turtles at French Frigate Shoals. This involved a phase change from a three year to a two year cycle in a female, and a change from a two year to a one year cycle in a male. The extent and significance of such shifts in Hawaiian *Chelonia* are presently unknown. Modulation of reproductive cycles may be a reflection of periodic changes in productivity or other ecological conditions of the turtle's resident foraging area.

3.17 Eggs

The mean weight of eggs laid at East Island by a 96 cm straight carapace length female was 50 g (range 45-54 g N=99). The mean diameter of these eggs was 44 mm with a range of 43 to 46 mm. Three of 50 egg clutches observed during oviposition at East Island were found to contain a few of the abnormally small or nonspherical eggs that have been reported in other *Chelonia* populations. The time required for an egg clutch to be deposited into a successfully excavated egg chamber ranges from approximately 20 to 30 minutes. This is considerably longer than the 10 minutes reported by Hirth (1965) for other *Chelonia* populations.

Predation on eggs does not normally take place at French Frigate Shoals. Although two species of ghost crabs (*Ocypode ceratophthalmus* and *Ocypode lacuis*) are present in relatively small numbers, neither of these crustaceans have been found burrowing into a nest. Although it is a rare occurrence at French Frigate

Shoals, nesting turtles will at times inadvertently dig into an existing clutch of eggs. Broken and exposed eggs from nests that have been disturbed in this manner have been observed being eaten by *Ocypode lacvis*, as well as migratory shore birds (ruddy turnstones, *Arenaria interpres* and golden plovers, *Pluvialis dominica*). On a single occasion, a wedge-tailed shearwater was recorded as having accidentally burrowed into a clutch of eggs at East Island. In a few instances, egg clutches have been laid too close to the shoreline, thereby being uncovered and washed away by subsequent wave action. Also a few turtles have been observed breaking large numbers of their own eggs as a result of harsh contact by a partially amputated hind flipper during the nest covering process.

From 1973 to 1979, an estimated 500 kg of unhatched green turtle eggs and dead hatchlings have remained buried in the ground each season at French Frigate Shoals and undergone decomposition. Although probably small in comparison to deposits from nesting seabirds, this chelonian organic matter nevertheless represents a valuable contribution to the soil fertility of the islands.

3.2 Hatchling Phase

Newly emerged hatchlings at French Frigate Shoals measure 53 mm in straight carapace length (range 48-59 mm N=556) and weigh 31 g (range 25-35 mm N=120). The dorsal surfaces of the hatchlings are black with white edges 2 to 3 mm wide on the flippers and a 1 mm wide white edge along the periphery of the marginal laminae. The ventral surfaces of the hatchlings are white with areas of black located on the flippers (see Balazs 55, 62 for color photographs).

Prior to emergence from the nest, Hawaiian green turtle hatchlings have been found to exhibit sudden bursts of activity when subjected to loud sound, such as produced by jet aircraft (Balazs and Ross 89, Barr 101). The biological effects of such noise on hatchlings, as well as developing embryos, are presently unknown.

The emergence of hatchlings at French Frigate Shoals is only known to occur at night, usually within a few hours after sunset. A firsthand observation of natural departure from the underground nest was made by the author during August 1974. Once emergence was initiated, the hatchlings crawled out singularly or in pairs in a moderately slow but continuous stream over a four to five minute period. This was followed by very slow circular movements in the immediate area of the nest site. During this period, which lasted for about two to three minutes, the hatchlings' heads were extended upward giving the appearance of intently observing some feature of the sky or horizon. Following these distinct movements, the hatchlings moved rapidly to the water in a number of different directions.

Although most hatchlings seem to enter the water at the shoreline closest to their nest site, all directions (except on Tern Island) will ultimately result in success due to the small land areas involved. Unnecessary terrestrial excursions would, however, result in an increased energy expenditure that could conceivably lessen the hatchlings' survival capabilities during the first few days in the pelagic environment. Groups of hatchlings on East Island have been recorded traveling in the direction of a bright moon, thereby considerably increasing the distance covered to reach the water.

Predation on hatchlings at French Frigate Shoals takes place by both species of ghost crabs, but *Ocypode ceratophthalmus* is consistently more

successful due to its larger size. Predation only occurs in or immediately above the narrow intertidal zone where both crabs periodically dig their burrows. Hatchlings are seized by the head, neck or front flippers and eaten either on the surface or inside a burrow. The internal organs and portions of the head, neck and pectoral muscles are usually the only parts consumed. The number of hatchlings eliminated from the population by ghost crabs probably does not exceed 5% or an estimated seasonal average of 1,200 individuals. Reducing the number of ghost crabs during the course of tagging and other research activities offers some potential as a management practice.

Although frigatebirds (*Fregata minor*) are among the seabirds present at French Frigate Shoals, they are not known to prey on hatchlings on land or in the inshore waters such as reported in other *Chelonia* populations (Hirth 265). Nocturnal emergence undoubtedly serves as a protective mechanism against such predation. Examinations of fecal matter at the nesting and roosting sites of frigatebirds have not resulted in the recovery of laminae or other indigestible particles of hatchlings. This suggests that predation is also not occurring in the pelagic waters surrounding French Frigate Shoals where frigatebirds periodically forage.

During the U. S. Coast Guard tenure at East and Tern Islands, newly emerged hatchlings were regularly disoriented and attracted to artificial lights and possibly vibrations from diesel generators associated with station facilities. Mortalities from thermal exposure subsequently resulted in those hatchlings that were not discovered by Coast Guard personnel and transported to the water.

Predation on hatchlings by carnivorous fishes at French Frigate Shoals does not appear to be significant. It is difficult, however, to assess such

impacts within the marine environment. From July to October 1974, 101 ulua (*Carangoides ajax*, *Caranx melampygus*), 16 wrasses (*Thalassoma purpuraceum*, *Bodianus bilunulatus*) and 13 gray reef sharks (*Carcharhinus amblyrhynchos*) were captured in the vicinity of East Island to examine stomach and intestinal contents for the presence of hatchlings. Major food items recovered included filefish (*Pervagor spilosoma*) and pieces of unidentified crabs and cephalopods, but no evidence of hatchling predation was found.

Hatchlings that emerge from nests in the center of East Island are coated with particles of humus, while those originating from pure calcareous sand areas along the periphery and at the west end emerge perfectly clean. For an unknown period of time after entering the water, hatchlings coated with humus emit a trail of organic material. It would be of value to know if this provides olfactory cues to potential fish predators, or somehow possibly serves as a deterrent to predation.

The types and levels of predation on hatchlings that emerge from nests at other islands in the northwestern segment of the Archipelago are presently unknown. Both species of ghost crabs as well as many of the same carnivorous fishes are also present at these locations.

Hawaiian *Chelonia* hatchlings that emerged from a captive nest at Sea Life Park on Oahu in 1976 were extensively preyed upon by wild mongooses, *Herpestes auro-punctatus* (Bourke *et al.* 1981). This mammal was first introduced to Hawaii in 1883 and is now present on all of the main islands except Kahoolawe, Lanai and Niihau.

3.3 - Juveniles, Subadults and Adults

3.31 Longevity

There is virtually no information on the life spans of Hawaiian *Chelonia* or marine turtles of any other population. The maximum age obtained could,

however, be considerable in view of the findings that turtles at certain resident foraging areas may require more than 59 years to reach maturity (Table 4). Tag recoveries of four females and eight males have been made in the Hawaiian Archipelago after periods exceeding nine years. All of these turtles were recorded as being adults when originally tagged. The longest time between initial tagging and last recovery for a female is 12.1 years, while the longest for a male is 14.3 years. In a 22 year old research program at Tortuguero, Costa Rica, the longest elapsed time reported for the recovery of a tagged nesting green turtle was 19 years (Carr *et al.* 1953).

Investigations by the author are currently underway to develop a method of estimating the age of Hawaiian *Chelonia* based on annuli discovered in the plastral and limb bones. These bands are most prominent in the dorsal segments of the hyoplastrons. Preliminary results have indicated a positive correlation between the number of bands and the size of the turtle. To supplement this research, autoradiographs are being attempted with sections of bones and laminae obtained from *Chelonia* at Enewetak Atoll (Marshall Islands) where nuclear devices were detonated during the 1950's.

3.32 Competitors

Monk seals with pups at times compete with green turtles for preferred basking space along the shorelines at French Frigate Shoals. Competition for basking space with this species has also been documented at the small sloping rock ledge at Necker Island (Balazs 72). Humans in the Northwestern Hawaiian Islands have periodically competed with *Chelonia* for terrestrial space. This has principally been in the form of military exercises, construction of facilities, commercial fishing, wildlife research, and pursuit of ornamental glass fishing floats (Amerson 30, Amerson *et al.* 32, Clapp and Wirtz 171, Clapp and Kridler 172, Ely and Clapp 211, Woodward 556).

At some of the resident foraging areas in the main islands, humans compete with green turtles for space by setting gill nets and by intruding into habitat with boats and Scuba. Although probably not a significant factor at the present time, competition also exists for certain kinds of benthic algae (*Codium*, *Ulva*, *Gracilaria*) that are eaten by both green turtles and humans (Abbott and Williamson 1, Fortner 228). Herbivorous fishes and some invertebrates in the Hawaiian Archipelago also utilize benthic algae as food sources, but the extent of this competition is not known.

3.33 Predators

Tiger sharks are virtually the only known natural predators of juvenile, subadult and adult Hawaiian *Chelonia*. Considering just the marine environment, this is essentially the case for all populations of Cheloniidae. Intensive shark research and eradication programs periodically conducted around the main Hawaiian Islands found that 18% (Ikehara 275), 10.8% (Fujimoto and Sakuda 230) and 12.7% (Tester 487) of the tiger sharks examined with food in their stomachs had been feeding on turtles. At French Frigate Shoals and Pearl and Hermes Reef, green turtles were recorded in 31% and 36%, respectively, of the tiger sharks captured that contained food (Taylor and Naftel 481, 482). An analysis of the recovered bones, laminae and beaks revealed the presence of nine different turtles in the five tiger sharks from French Frigate Shoals, and eight different turtles in the four tiger sharks from Pearl and Hermes Reef (Balazs 70). A single shark at Pearl and Hermes Reef accounted for five turtles that ranged from an estimated 53 to 64 cm in straight carapace length. Four of the turtles recovered from sharks at French Frigate Shoals were found to be adults of unknown sex ranging from an estimated 81 to 94 cm in straight carapace length. The sizes of the tiger sharks captured ranged from 2.8 to 4.3 m, but significant relationships ($p < .05$) were not

found between size of the turtles eaten and the shark's length or mouth width, which ranged from 26 to 51 cm. Based on these findings, it may be necessary to revise the prevalent belief that natural predation on adult green turtles is minimal (Hirth 265). The digestion rates of green turtle parts in tiger sharks are unknown, therefore it is not possible to determine how long this material may have been retained in each stomach. Due to the comparatively large quantity of laminae and beaks present among the recovered items, it seems likely that keratinized structures are the most difficult to digest, if in fact they can be digested at all. It has been suggested that indigestible items eaten by tiger sharks may be periodically eliminated by regurgitation.

The feeding mechanism of the tiger shark includes heavy sawing actions by both jaws which can effectively cut up large green turtles into pieces suitable to swallow. However, for smaller size turtles this is apparently not necessary. On numerous occasions juvenile Hawaiian *Chelonia* ranging from 35 to 50 cm in straight carapace length have been recovered whole from tiger shark stomachs (Taylor and Naftel 481, 482, Tester 487, C. Chiswick and D. Hertz, personal communications). Tinker (490, 492) reported that a 23 kg turtle was found in a large tiger shark caught off Oahu in 1935.

Tiger sharks have been regularly recorded at French Frigate Shoals in water only a few meters deep adjacent to the various islands (Balazs and Whitton 90). In April 1956 a 3 m shark was observed attacking a large turtle off Whale-Skate Island (Pacific Ocean Fisheries Investigations 392). In June 1974, the author watched a 2 m tiger shark beach itself momentarily on East Island during the unsuccessful pursuit of a juvenile green turtle that had fled to the shoreline. Two tiger sharks were also recorded swimming close to a copulating pair of turtles and three male escorts, but no attack resulted. In August 1978, a large tiger shark was observed for two hours repeatedly trying to reach a dead adult turtle with no head or flippers that had

become beached in the wavewash at Trig Island (G. C. Whittow, personal communication). In view of these sightings, it is significant to note that during an 11 month period on East Island in 1946, former Coastguardsman H. E. Finch (personal communication) never saw a tiger shark even though he regularly set baited hooks and caught numerous *Carcharhinus amblyrhynchos*.

Approximately 10% of the turtles nesting on East Island have healed or fresh injuries or amputations of their hind flippers that are suggestive of shark attack. A tagged female released from captivity off Oahu in December 1973 (Anonymous 611, 613, 616) was observed 25 months later basking on Whale-Skate Island with a front flipper freshly amputated at the humerus. An adult male with a freshly amputated front flipper was seen basking at East Island during July 1976. Two other adult males with a completely missing but healed front flipper have also been recorded while basking. A tagged adult female with one front and both hind flippers missing but partially healed was seen basking at Trig Island in June 1973 (Olsen 384). An adult female tagged at East Island in 1973 was recovered 13 months later off Maui and found to have a recently amputated front flipper (Balazs 57). A turtle with a missing front flipper was seen at Gin Island in 1923 (Wetmore 541). At Lisianski Island, Taylor (475) recorded an adult male in a moribund condition with its tail freshly amputated.

In a trial calculation of the depletion rate in the Hawaiian *Chelonia* population, Hendrickson (262) speculated that no less than 100, and possibly as many as 1000, turtles per year of 23 kg and above were lost to tiger shark predation.

The only other natural predator of post-hatchling green turtles documented in the Hawaiian Archipelago is the large grouper, *Epinephelus tauvina*. In October 1974 a 205 kg specimen caught off Molokai was found to contain a partially digested but whole juvenile turtle measuring approximately 52 cm in straight carapace length

(K. Mench, personal communication). Sightings and captures of these groupers are rare in the Hawaiian Archipelago, but specimens as large as 365 kg have been documented.

* 3.34 Epizootics, diseases, abnormalities and injuries

Barnacles commonly found on Hawaiian *Chelonia* include *Chelonibia testudinaria* (Bryan 143, Edmondson 205, Gordon 237) and *Platylepas hexastylus* (identified by W. J. Cooke). *Chelonibia* is usually confined to the carapace, plastron and head, while *Platylepas* attaches itself principally to the skin regions, occasionally in large numbers. Large specimens of *Chelonibia* can measure 50 mm in diameter at the base, while *Platylepas* usually does not exceed 6 mm. Adult turtles consistently host larger specimens of these two barnacles than the juvenile or subadult turtles. The burrowing barnacle, *Stephanolepas muricata* (identified by W. J. Cooke), has been recovered from the front flipper of a juvenile in Kaneohe Bay, Oahu, and is apparently a rare species in Hawaiian *Chelonia*.

Two specimens of the piscicolid leech, *Ozobranchus branchiatus* (identified by M. D. Dailey), have been recovered from a juvenile green turtle at Necker Island. During 1978, green, hawksbill and loggerhead turtles on display at Sea Life Park became heavily parasitized with *Ozobranchus margo* (identified by M. D. Dailey). This infestation is thought to have originated from a stray loggerhead that had been found off Molokai and brought into captivity (Altonn 20, McKinney 351). At present, no other records exist for *Ozobranchus* in the Hawaiian Archipelago.

The buccal cavity of Hawaiian *Chelonia* occasionally contains one or two specimens of the talitroidean amphipod, *Hyachelia tortugae* (identified by W. J. Cooke). This crustacean has also been found on the neck and hind flippers living in association with superficial skin lesions.

In June of 1974, a remora (*Echeneis* sp.) was observed attached to the plastron of an adult female off East Island.

The red alga, *Polysiphonia tsudana* (identified by D. J. Russell), commonly occurs on the skin of Hawaiian *Chelonia* and occasionally on the plastron and Inconel tags (see Newbert *et al.* 375 for color photograph). This species was first described from the neck of a green turtle at Laysan Island (Hollenberg 270). Other algae that have been periodically found by the author on the skin, carapace and plastron of Hawaiian green turtles include the following (identified by D. J. Russell): Rhodophyta (red) - *Polysiphonia dotyi*, *Acrochaetium gracile*, *Falkenbergia rufolanosa*, *Melobesia* sp. (encrusting); Phaeophyta (brown) - *Sphacelaria furcigera*, *Sphacelaria novae-hollandiae*, *Ectocarpus indicus*; chlorophyta (green) - *Enteromorpha clathrata*; Cyanophyta (blue-green) - *Lyngbya majuscula*, *Lyngbya cinerescens*, *Oscillatoria* sp. At Necker Island, intertidal crabs (*Grapsus grapsus*) have been observed on the carapace and flippers of basking turtles feeding on algal mats. When the turtles return to the water, surgeonfish (*Acanthurus sandvicensis*) are also attracted to these epizoids for grazing purposes (Balazs 72). At French Frigate Shoals, discrete underwater sites have been identified where green turtles regularly position themselves while wrasses and surgeonfish feed on epizoids. A color photograph showing this symbiotic behavior off the north shore of Tern Island appears in an article by Eliot (208).

Neoplastic growths ranging from small warts to huge masses 25 cm in diameter occur on 5 to 10% of the green turtles observed during each breeding season at French Frigate Shoals. Common sites of these neoplasms include the neck (Kridler 322), flippers, tail and fold of flesh where the tags are attached. In many of the affected turtles small growths also occur in association with the eyes, apparently originating from the conjunctiva and sclera. Two adult males seen basking at East Island had eye growth so extensive that most vision was

eliminated. However, except for the presence of these growths, the turtles appeared healthy. An array of growths has been obtained from moribund juvenile, subadult and adult turtles found off Oahu since 1977, as well as from an individual held in captivity for more than five years. These specimens were submitted to the Registry of Tumors in Lower Animals (Smithsonian Institution) where they were analyzed and subsequently identified as benign fibropapillomas that have been occasionally reported in other marine turtle populations. The formation of these growth in Hawaiian *Chelonia* is described as follows. The epidermis proliferates and forms pegs extending into the dermal connective tissue. At the same time, dermal papillae containing connective tissue, vascular channels, and associated melanophores grow between the epidermal pegs to provide nourishment. The surface epidermis produces abundant layers of keratin and occasionally trapped cells within the dermis form pearls or epidermal cysts containing concentric rings of keratin. Subsequent enlargement results to an increasing extent with expansion of the fibrous component. Larger tumors are therefore mostly a monotonous field of fibrocytes with some interspersed melanophores and a few epidermal pegs near the surface. Invasion of the underlying muscle does not usually take place (J. C. Harshbarger, personal communication and 255, 256, 257). The etiology of fibropapillomas is unknown. In Hawaiian *Chelonia* they are not associated with the foreign organic materials (leeches, barnacles, algae) that have been suggested as possible causes in other marine turtle populations. The possibility of a viral origin is presently being investigated by electron microscopy of tissue biopsies from the prickle cell layer of the epidermis of early growths on Hawaiian *Chelonia* (J. C. Harshbarger, personal communication). Other possible causes include repeated contact with carcinogenic substances, such as might occur at sewage discharges or from corroding Monel tags,

and excessive exposure to solar radiation while floating at the surface or basking. Fibropapillomas on green turtles may not, however, be a new occurrence in the Hawaiian population. A photograph taken in 1923 at French Frigate Shoals shows a basking turtle with what appears to be a growth on the dorsal surface of its left front flipper (Tinker 492, Anonymous 568). It is likely that some turtles with fibropapillomas are more susceptible to tiger shark predation due to decreased vision and maneuverability while swimming.

A salt crystal deposit weighing 8 g and measuring 20 mm in diameter was extracted from the corner of the left eye of a juvenile green turtle at Lisianski Island. This condition probably represented some dysfunction of the lacrimal gland or blockage of the duct that transports the hypersaline secretion.

During July 1978, a turtle that nested on Laysan Island approximately 285 m inland became disoriented during her return to the ocean and died the following morning from thermal exposure (P. and B. Johnson, personal communication). There were no growths on the turtle's eyes or other external signs to explain this abnormal behavior. Similar orientation problems by nesting *Chelonia* have also been recorded by the author at Canton, a large, low coral atoll at 2°50'S, 171°43'W (see also Pritchard 418).

Captive growth studies conducted with 120 green turtles collected as hatchlings at French Frigate Shoals resulted in 31 mortalities from various causes by seven months of age (Bardach 98, Bardach and Helfrich 99, 100). Post-mortem examinations revealed that six of these turtles had lesions consisting of focal granulomas characteristic of tuberculosis. Bacilli identified as *Mycobacterium avium* Serotype 8 were isolated from one of the two specimens subsequently cultured (Brock *et al.* 134). The *Mycobacterium avium* complex is usually associated with poultry, cattle and swine, and this isolation from

Chelonia apparently represented the first record for a poikilotherm. The source of the infection was not determined, however neonatal contact in the underground nest with substrate contaminated by seabirds would appear to be a plausible route. No information presently exists on the occurrence of *Mycobacterium* in naturally occurring seabirds or green turtles in the Hawaiian Archipelago.

Salmonella weltevreden (identified by R. M. Nakamura) and *Salmonella san-diego* Type B (identified by M. H. Crumrine) have been isolated from the feces of captive reared Hawaiian *Chelonia*, but again nothing is known of occurrence in the wild.

Paralysis of a front flipper due to aseptic necrosis of the head of the humerus has been observed in two captive reared Hawaiian *Chelonia*. The etiology of this affliction could not be determined (M. H. Crumrine, M. W. Balk, N. E. Palumbo and G. Liese, personal communications). Necrosis of unknown origin has also been found in the terminal scales of the front flippers of juveniles at Kure (Balazs 73).

Injuries to the carapace and plastron of Hawaiian *Chelonia* are known to result from violent contact with rocks and other underwater substrate accidentally encountered while foraging in rough surf close to shore (Wright *et al.* 557). At certain coastal areas on the island of Hawaii, tsunamis have carried juvenile and subadult green turtles over 100 m inland where they became stranded and unable to return to the water without human assistance (A. L. Howard, personal communication). It is unknown how extensive these strandings may be along remote coastal areas of the Archipelago following a large tsunami.

Both injuries and mortalities of Hawaiian green turtles are known to occur incidental to fishing activities directed at other species (Anonymous 570, 583). This can result from contact with fishhooks, and from entanglement in gill nets, rope, and monofilament fishing line. In addition, discarded items can at times be hazardous to turtles, as evidenced by a juvenile captured off Oahu that had a part from a plastic container stuck around its neck.

3.4 Nutrition and Growth

3.4.1 Food sources

Green turtles that reside in coastal areas of the Hawaiian Archipelago have been documented by the author feeding on 56 species of algae, one marine angiosperm and nine types of invertebrates (Table 9). However, nine species of algae out of the approximately 400 species present in the Archipelago account for the major food sources utilized (Table 10). *Codium* and *Ulva* are major dietary components of juveniles, subadults and adults in both segments of the Archipelago, joined by *Pterocladia* and *Amansia* in the main islands, and *Caulerpa*, *Turbinaria* and *Spyridia* in the Northwestern Hawaiian Islands (Balazs 71, 72, 75, 81, 82). In 1933 Galtsoff (231), quoted by Amerson *et al.* (32), noted that the stomachs of green turtles examined at Pearl and Hermes Reef contained large amounts of *Codium*. Abbott and Williamson (1) indicated that Hawaiian green turtles are known to eat *Sargassum*, thereby probably accounting for its native name of limu honu. Hirth (265) listed "green algae" as the food of adult turtles off Maui. Wetmore (542), quoted by Mellen (353), stated that green turtles in the Northwestern Hawaiian Islands "browse in submarine fields of algae." Prior to the author's research program, these were the only published references on the food sources of Hawaiian *Chelonia*.

The methods used to determine the food sources of Hawaiian *Chelonia* listed in Tables 9 and 10 have included: 1) analysis of gastrointestinal contents salvaged from mortalities due to tiger shark predation, accidental and intentional human capture, and strandings of unknown causes; 2) direct observations of foraging made from shore and underwater with Scuba; 3) recovery of incompletely digested food from fecal pellets found at resident foraging areas; 4) recovery of food directly from the mouths of turtles captured uninjured

while actively feeding; and 5) sampling of stomach contents using a flexible plastic tube (Balazs 86) and a small diameter flexible grasping tool (Kam and Balazs 286) inserted through the esophagus.

• The distribution and abundance of benthic algae in the Hawaiian Archipelago are not well known, however, standing crop densities of the species preferred by green turtles appear to be far greater in the main islands. For example, certain foraging areas around the islands of Hawaii, Maui, Oahu and Kauai have dense growths of the red alga, *Pterocladia capillacea*, while in the Northwestern Hawaiian Islands this is a rare species only known to occur in small quantities at Lisianski Island. Concomitantly, *Amansia glomerata* is abundant at many main island foraging areas, but relatively scarce in the northwestern segment of the Archipelago. *Caulerpa racemosa*, a green alga regularly eaten by *Chelonia* at certain sites in the Northwestern Hawaiian Islands, has never been found as a dietary component in the main islands even though it occurs at a number of locations. It is significant to note that the genus *Caulerpa*, and particularly the species *racemosa*, contain the toxic constituent "caulerpicin" which can produce symptoms in humans similar to ciguatera fish poisoning (Doty and Aguilar-Santos 203). It is unknown what effects, if any, caulerpicin may have on green turtles. *Turbinaria ornata* and *Spyridia filamentosa*, dietary components in the Northwestern Hawaiian Islands, are also not eaten in the main islands where they at times grow in the same general area as the favored *Pterocladia capillacea* and *Amansia glomerata*.

Marine angiosperms, such as turtle grass, *Thalassia testudinum*, constitute the principal food source for a number of *Chelonia* populations (Hirth 265), however the only species represented in the Hawaiian Archipelago is *Halophila hawaiiiana*. This seagrass has oval blades 1 to 3 cm long and only occurs in small meadows of low densities around the main islands and at Midway.

It is of interest to note that two species of red algae, *Acanthophora spicifera* and *Hynea musciformis*, recorded in the diets of green turtles in the main islands are introductions to Hawaiian waters from Guam and Florida, respectively. In addition, the recovery of *Polysiphonia tsudana* from the stomach of a juvenile at Kure suggests that this turtle was grazing on either its own or another turtle's epizoic algal mat.

Juvenile and subadult turtles in the Northwestern Hawaiian Islands, particularly at Midway and Kure, have been observed voraciously feeding on the invertebrates *Physalia*, *Velella* and *Janthina* that periodically drift into the coastal areas. The eyes and gastrointestinal tracts of these turtles are apparently not adversely affected by the nematocysts present in both *Physalia* and *Velella*. In the main islands the small black sponge, *Chondrosia chucalla*, is also periodically eaten by green turtles, usually in association with *Codium edule*. Examinations of fecal pellets have shown that these sponges, as well as pieces of *Codium* and other algal species, are able to pass through the gastrointestinal tract in a relatively undigested state. Although small crustaceans can sometimes be found living on algal filaments, these animals have not been present in the stomach samples examined.

Synthetic items such as plastic fragments, pieces of plastic bags, cloth, string and small diameter polypropylene line have occasionally been found in Hawaiian *Chelonia*. An adult female captured by a fisherman in November 1978 off the north shore of Lanai contained large pieces of both black and clear plastic bags throughout its intestines. This material was also present in fecal matter in the rectum, thereby indicating that blockage of the tract had not taken place. Plastic items of this nature found floating at the surface appear to be mistaken by some turtles for coelenterates or other edible invertebrates.

Fragments of terrestrial vegetation in the stomach, as well as tar stains in the mouth have also been occasionally found in Hawaiian *Chelonia*.

The food sources of Hawaiian *Chelonia* less than 35 cm living in the pelagic environment are completely unknown due to the absence of human contact (section 2.22). It is logical to assume that during this period the turtles are carnivores feeding on invertebrates that occur at or near the surface. In pelagic waters surrounding the Hawaiian Archipelago, this could include *Physalia*, *Velutella*, *Janthina*, the megalops stage of some portunid crabs, and immature individuals of certain oceanic squids that come to the surface at night in large numbers (i.e. *Symplectoteuthis ovalaniensis*, *Onychoteuthis banksi* and *Hyaloteuthis pelagica*). Light organs present in these squids could conceivably serve as attractants to the young turtles.

3.42 Feeding behavior

Hawaiian *Chelonia* spend most of their lives residing in coastal areas where they alternate between periods of feeding and quiescence (sections 2.21, 2.22). The habitat characteristics of these resident areas can differ throughout the Archipelago, consequently variations exist in feeding strategy and behavior.

In the Kau District on the island of Hawaii, feeding takes place along lava coastlines that lack protective reefs. The major food source, *Pterocladia capillacea*, grows in shallow water close to shore, often on rocks just below the low tide line and in areas where fresh water enters the ocean from underground springs. Although a few partially sheltered bays are present, most foraging occurs under turbulent conditions resulting from exposure to ocean swells and tradewind waves. Observations of turtles made from adjacent coastal cliffs have indicated that considerable swimming and maneuvering are required while foraging

in order to prevent contact with the bottom and to travel to the surface at regular intervals for respiration. Under these rough surf conditions, only a single rapid breath is usually taken before returning to the bottom. If human activity is observed on land during the surface interval, a turtle will frequently terminate feeding and retreat to deeper water. Along Bellows Beach on Oahu, the feeding areas used by *Chelonia* consist of sand bottoms 25 to 100 m from shore where detached pieces of *Codium*, *Ulva* and other algae periodically collect as a result of wave action and currents. Subtidal reefs located further offshore buffer the coastline from large surf, thereby making it possible for turtles to forage with comparatively little effort. A greater tolerance is displayed in this area to human activities, such as recreational swimming and beach use. This is probably due to the fact that turtles are seldom pursued or killed at Bellows, while along the Kau coastline such activities are a periodic occurrence. French Frigate Shoals is another representative foraging area for Hawaiian *Chelonia* in which feeding behavior displays some adaptation to the characteristics of the habitat. At this location, aggregations of juveniles 37 to 55 cm in straight carapace length feed on *Caulerpa*, *Codium* and at times small anthozoans that grow on calcareous reef structures near the islands of East, Whale-Skate and Tern. Although the tidal difference at French Frigate Shoals is only about one meter, foraging is generally restricted to periods of high tide due to the shallow depths present at these sites. Furthermore, many of the recesses in the substrate where the food sources grow are only large enough for juvenile turtles to reach into with their heads and beaks. Turtles foraging within French Frigate Shoals are not usually subjected to rough surf conditions. Surface intervals for respiration therefore frequently last two minutes or longer, during which time from three to eight deep breaths may be taken. The subsequent submergence times

while feeding range from approximately 5 to 15 minutes. While grazing on a food source, juveniles will frequently place themselves in an almost vertical position with the head down and the hind flippers extending at right angles. This appears to help stabilize the turtle directly over the desired feeding site.

Stomach samples from adults of both sexes at French Frigate Shoals have shown that feeding takes place during the breeding season. This is usually not thought to occur in other *Chelonia* populations (Hirth 265), probably due to the scarcity of food at many breeding sites.

At all of the resident foraging areas thus far investigated, tagged Hawaiian *Chelonia* have been found to repeatedly feed at the same locations. This fixation has been documented on both a short-term basis (daily and weekly), and for longer periods ranging up to 37 months (Balazs 81).

At resident foraging areas in the main islands, research techniques for tagging turtles have involved the use of carefully monitored large-mesh tangle nets (Balazs 64, 81, Kam and Balazs 286). Most of these captures have involved turtles that entered the net at night, frequently from 1 to 3 hours before sunrise during periods of incoming tides. This has occurred in total darkness from heavy cloud cover, as well as during various phases of the moon with some illumination present. Mouth and stomach samples from many of these turtles have shown that active feeding was taking place. Sensory cues to supplement vision would appear to be necessary for commuting at night from resting sites to feeding areas. Olfactory cues may aid in this short-range navigation due to the fact that many of the algae eaten by turtles have pronounced odors. In addition, freshwater seepage associated with pastures of *Pterocladia* could provide a traceable salinity gradient. Tactile cues with the flippers while slowly swimming along the bottom would also seem to be a

plausible orientation component for any short-range movement in the dark. Ridgeway *et al.* (433) found that Hawaiian *Chelonia*, and presumably all green turtles, are able to hear low frequency sounds (60-1000 Hz), with maximum sensitivity occurring in the range of 300 to 400 Hz. Hirth (265) has even suggested the possibility that green turtles may possess some sonar capabilities. Nevertheless, the simple detection of sounds originating from certain fish, invertebrates and the surf could be of some navigational value at night. With respect to foraging without the benefit of vision, it is also of interest to note that a moribund juvenile with massive fibropapillomas on both eyes recovered from Kaneohe Bay was found to have relatively fresh algae in its stomach.

Examinations of stomach contents have revealed that Hawaiian *Chelonia* of all sizes generally bite off only small pieces of algae while foraging. The deeply grooved and serrated cutting edges of the beaks appear to be well adapted for this purpose. The foremargin of a front flipper rubbed against the beaks also aids in shearing food, as evidenced by an underwater observation of a juvenile feeding on *Codium edule* at Kure. In shallow water off Kahoolawe in the main islands, a juvenile was observed using its upper beak to scrape off an algal mat of *Gelidium* sp. growing on a rock. Approximately 10% of the stomach contents of an adult from Lanai was found to consist of *Halophila* blades. The cropping of this small seagrass apparently took place in a delicate manner in that no sand or other fine substrate in which *Halophila* grows was found in the stomach contents.

Short-term changes in the food preferences of some turtles have been detected by examining the complete contents of excised gastrointestinal tracts. Differences have at times been found in the species of algae present at various distances along the intestines, and in the two compartments that comprise the stomach. Periodic dietary shifts of this nature probably help Hawaiian *Chelonia*

meet their requirements for essential nutrients (i.e. amino acids, fatty acids, vitamins, minerals) that may be more concentrated in some species of algae. Certain of these nutrients may also be synthesized by microbial action within the intestine. As with other vertebrates, the nutritional requirements of green turtles in the wild would vary with age, activity and reproductive condition.

It is not unusual for juvenile and subadult green turtles in the Hawaiian Archipelago to bite on hooks baited with squid, shrimp and fish flesh (Carter 158, Anonymous 583). These carnivorous interludes probably represent regressions to the feeding habits exhibited while living in the pelagic environment.

3.43 Growth rates

The mean rates of growth of immature green turtles (37-59 cm) occurring naturally at seven resident areas in the Hawaiian Archipelago have been found to range from .08 to .44 cm per month in straight carapace length (Table 4). The most rapid growth takes place along the Kau coastline of Hawaii (.38-.52 cm/mo), while the slowest occurs at French Frigate Shoals (.02-.13 cm/mo) and Kure (.04-.12 cm/mo). In addition to the growth data presented in Table 4, 34 healthy appearing immature turtles have been recovered after periods ranging from 2 to 20 months in which no measurable growth could be detected. This has included six turtles at Midway, three at Lisianski, 24 at French Frigate Shoals and one at Necker. One of the turtles at French Frigate Shoals was a 68 cm subadult that showed no increase in straight carapace length after an interval of 20 months. The turtle at Necker was a 42.5 cm juvenile that was recaptured after a 17 month interval. Although the apparent absence of growth could in some cases possibly be attributed to measuring errors, this is not believed to be a significant factor in that the author has personally taken most of the initial and recovery

measurements. The causes and implications of cessation of growth among some turtles are unknown and further investigations are warranted.

In addition to utilizing large-mesh tangle nets, the capture of immature turtles for growth studies in the Hawaiian Archipelago has been accomplished with long-handled scoop nets, and by hand while diving with Scuba. In the Northwestern Hawaiian Islands, particularly at Lisianski, periodic basking also provides access to these turtles. The use of curved carapace length for detecting growth has been found to be generally unreliable due to variations in positioning the flexible measuring tape (see Kridler 322), and changes in the curvature of the carapace that appear to be independent of an increase in size. The use of body weight has also been found to be unreliable. This is probably due to differences in the amount of food material in the gastrointestinal tract, a component that can comprise up to 18% of the weight of juvenile Hawaiian *Chelonia* (Balazs 81).

The different rates of growth exhibited by immature turtles at various locations in the Archipelago are most likely a function of the sources and abundance of food at the resident areas (section 3.41). Seawater temperature would be expected to have some influence, but this is not evident based on the available data. At Kure and Midway, and probably extending to the southeast as far as Lisianski, mean monthly sea surface temperatures range from a low of 20.5°C during February, to a high of 26.2°C during August and September (Clapp and Wirtz 172, Galtsoff 231). This is 2 to 3°C cooler than French Frigate Shoals (Figure 5) where essentially the same growth rates have been recorded. Temperatures at French Frigate Shoals are similar to the main islands where considerably faster growth occurs. It is unlikely that a genetic basis accounts for the differences in growth considering the polygamous behavior displayed by adults during each breeding season at French Frigate Shoals (Balazs 57).

A growth rate of .18 cm per month was recorded at French Frigate Shoals for a subadult female released off Oahu 28 months earlier after an extended period in captivity (Table 11). A 42.5 cm juvenile raised in captivity from a hatchling was found to be the same size when recovered by the author 11 months later while diving along the Kau coastline. Two of 26 other juveniles raised from hatchlings and released at French Frigate Shoals (Altonn 15) established residency around an iron seawall off the northwestern corner of Tern Island. U. S. Coast Guard personnel regularly fed these turtles fresh fish scraps and the author was subsequently able to capture them for growth measurements (Table 11). One of the turtles grew .71 cm per month over an eight month period, thereby constituting the most rapid growth rate thus far documented for a Hawaiian green turtle living in the wild. This turtle subsequently disappeared, while the other one was found washed up on the beach and dead of unknown causes.

For comparative purposes, growth data are also presented in Table 11 for four Hawaiian *Chelonia* raised in captivity from hatchlings for periods ranging from 57 to 81 months. The diets fed to these turtles consisted of various combinations of pelleted dry feed ingredients (i.e. fish meal, meat and bone meal, soybean meal, corn), as well as fresh frozen squid and fish. These data show that at least 19 months were required to reach a size of 35 cm, after which the rate of growth declined considerably. Bourke *et al.* (131) present growth data in the form of weight increases for 46 Hawaiian *Chelonia* hatched in captivity and raised to six months of age.

The growth rates of Hawaiian *Chelonia* after maturation have been documented through the remeasurement of adults during each breeding season at French Frigate Shoals. Increases for 17 females and one male ranged from .01 to .12 cm per month (24-75 months), with a mean of .04 cm per month (Table 12). This suggests that

the rates of growth for at least some Hawaiian *Chelonia* decline significantly once maturity has been reached. A considerable length of time would therefore be required for a turtle that matured at a small size (81 cm) to grow to a large size (see sections 3.12, 3.31 and Hirth 265). The differences in growth rates recorded for mature turtles (.01-.12 cm/mo) may also be a function of the sources and abundance of food at the resident area (section 3.16). If this is indeed the case, mature turtles that show the most rapid growth could be identified as having remigrated from areas in the main islands. Data presented in Table 12 provide some support for this proposition in that female 5016 exhibited one of the most rapid growth rates (.09 cm/mo) and is known to have originated from the Kau District on the island of Hawaii (section 3.52).

Table 13 presents growth rates for both immature and adult Hawaiian *Chelonia* captured from the wild and held for extended periods in captivity at Sea Life Park on Oahu. The diets of these turtles consisted of fresh frozen squid and fish.

3.5. Post-hatchling Movements

3.51 Dispersal and developmental migrations

The dispersal of green turtle hatchlings from French Frigate Shoals into the pelagic environment takes place by surface currents and vigorous swimming (section 2.22). After an undetermined period of time in the open ocean, during which unknown routes are followed, juveniles of approximately 35 cm arrive at coastal areas throughout the Hawaiian Archipelago. The recruitment of these turtles at islands to the northwest of French Frigate Shoals could be a direct result of northwesterly currents that prevail for hatchlings entering the water during the month of July (Figure 4). In addition, the low level of breeding

that occurs principally at Laysan, Lisianski and Pearl and Hermes Reef may be a further source of juveniles in this segment of the Archipelago. The recruitment of juveniles in the main islands is more difficult to theorize. One possibility is that during the peak hatching month of August, prevailing surface currents transport hatchlings in a northerly direction for a two month period to approximately $28^{\circ}40'N$ (Figure 4). At this point instead of turning to the southwest along with the same current system, the turtles swim to the vicinity of 30 to $31^{\circ}N$ where winter surface currents of 19 to $20^{\circ}C$ travel eastward. Over an ensuing period of six months or longer, the turtles could be carried by a gyre that ultimately delivers them to the main islands. Another possibility is that a far larger circular transport system is involved in which hatchlings are carried well to the west of the Hawaiian Archipelago and around a vast area of the North Pacific back to the main islands. Of course it is also conceivable that some of the turtles leaving French Frigate Shoals are not carried by the currents, but rather swim against the currents on a course directly toward the main islands. Nevertheless, whatever oceanic routes of dispersal are involved, there is little doubt that juveniles less than 35 cm are residing somewhere outside of the coastal areas where larger turtles feed and rest. This is supported by the dearth of direct sightings, as well as by the absence of juveniles less than 35 cm in the stomachs of tiger sharks. The single observation of a 20 to 25 cm juvenile reported at French Frigate Shoals (Balazs 57) was undoubtedly a rare occurrence involving a stray individual.

Juveniles measuring 35 to 40 cm that are believed to be recent arrivals to coastal areas have on a few occasions been observed by the author at Kure, Midway, Oahu, and along the Kau District (Wright *et al.* 557). These new recruits were discernible by an absence of epizoids and superficial scratches, and by the

presence of thin translucent edges to the periphery of the marginal laminae and terminal scales on the flippers. In addition, the cutting edges of the lower beak had more pronounced serrations than other juveniles of the same or a slightly larger size. All of these characteristics could be expected to disappear rapidly after establishing resting and herbivorous foraging habits in a coastal area.

Most evidence accumulated to date indicates that after leaving the pelagic environment Hawaiian *Chelonia* reside in the same general coastal area for extended periods, possibly throughout their entire lifetime except for remigrations for reproduction. This extended residency concept is at least partially supported by the fact that all sizes of turtles, from 35 cm juveniles to mature adults, are frequently present along a given coastal area. Some specific foraging sites have been identified that can only be used by juveniles (section 3.42), however habitat employed by larger turtles is usually only a short distance away. The recovery of tagged immature turtles after periods ranging up to 37 months has also provided evidence for extended residency. With the exception of two turtles, all recaptures (146 out of 524 - Table 4) have been made in the same foraging and resting areas where initial tagging occurred. At French Frigate Shoals, recoveries have shown that no movement takes place between sites separated by as short a distance as 8 km. At Kure a tagged turtle was found resting under the same coral ledge where it had been captured 13 months earlier (Balazs 81). The only two recoveries that indicated movement of any distance involved the weak 38 cm juvenile tagged at Midway and found downwind at Wake (section 2.1), and a 40 cm juvenile also tagged at Midway that was reported to the author seven months later as having been recovered and released alive in Hilo Bay on the island of Hawaii. This latter

case involves an ocean distance of approximately 2,300 km against the prevailing winds and currents in the latitudes of the Hawaiian Archipelago. Although two Monel tags were originally placed on this turtle, only one tag was found and recorded at the time of recovery. The possibility must therefore be considered that the tag number was misread due to corrosion or other causes. If such movements can in fact be substantiated through additional recoveries, immature turtles residing in the northwestern segment of the Archipelago would constitute a significant factor in recruitment to the main islands. Such a recruitment system was theorized by the author (Balazs 57) prior to the accumulation of existing data which supports the concept of an extended residency at the coastal area entered from the pelagic environment. This theory was based in part on observations of groups of juveniles 35 to 60 cm periodically occurring at French Frigate Shoals. These sightings suggested that developmental migrations of some nature were taking place (Balazs 57). However, subsequent tagging revealed that the same turtles were involved, and not new aggregations as originally speculated. The regular disappearance of these turtles for several weeks and possibly even months at a time has still not been resolved. One explanation would be that a form of dormancy is periodically being undertaken at sheltered underwater locations. Such behavior has been documented for *carrinegra* in the Gulf of California, but is presently unknown for Hawaiian *Chelonia*.

If significant levels of recruitment to the main islands occur through developmental migrations from the northwestern segment of the Archipelago, then revisions would be necessary in the projected number of years needed for Hawaiian green turtles to reach maturity (section 3.12 and Table 4).

Since January 1973, 10 adult and 31 subadult green turtles have been returned to the wild after extended periods in captivity. The dispersal patterns of the five turtles that have been recaptured in the main islands are presented in Table 14 and Figure 8.

An experimental model for the life history and habitats of Hawaiian *Chelonia* is presented in Figure 9.

3.52 Remigrations

Adult Hawaiian *Chelonia* periodically travel between their resident foraging areas and French Frigate Shoals for reproduction (sections 2.21, 3.16). These remigrations have been documented for both males and females through 52 long distance tag recoveries, 31 of which involved French Frigate Shoals and the main islands, and 21 that involved French Frigate Shoals and the northwestern locations of Laysan, Lisianski and Pearl and Hermès Reef (Table 15, Figure 10). Details of the 16 female and four male tag recoveries that have been made since June 1973 are presented in Table 16.

The recoveries in the main islands, of turtles that were tagged while at French Frigate Shoals, mostly represent mortalities resulting from direct capture by fishermen. However, recoveries at Laysan, Lisianski and Pearl and Hermes Reef were of basking turtles that remained viable members of the population and, in several cases, were recovered again at later dates. Records of remigrations in the Hawaiian Archipelago are unique among marine turtle populations due to the two-way tagging opportunities afforded by the basking behavior, and by the research emphasis placed on turtles in their resident foraging areas. These factors have made it possible to document movements from the resident areas back to the breeding grounds, a missing segment in all one-way tagging

programs where it is only feasible to tag nesting turtles. The documentation of long distance movements by adult males is, of course, in itself a rare research occurrence. The results of these various opportunities with Hawaiian *Chelonia* are dramatically illustrated by male 1060 in Table 16 which was tagged at Pearl and Hermes Reef in 1964, recovered at East Island, French Frigate Shoals in 1976, and recorded back at Pearl and Hermes Reef one year later in 1977.

Tag recoveries demonstrate that the breeding assemblage at French Frigate Shoals is comprised of adults that remigrate from widely separated resident areas. The longest voyages thus far recorded are from French Frigate Shoals to Hilo Bay (tag 2229 Table 16), and from the Kau District to French Frigate Shoals (tag 5016 Table 16), both of which represent one-way ocean distances of approximately 1,100 km. Fourteen other recoveries (4 males, 10 females) have been made between Pearl and Hermes Reef and French Frigate Shoals, a distance of 1,050 km. Mating is therefore taking place between some males and females that live in areas separated by as many as 2,150 km. A minimum rate of travel of 23 km per day during these remigrations has been computed from a relatively short term recovery between French Frigate Shoals and Kauai (tag 853 Table 16). If the contour of the adult female's carapace is indeed more highly arched (less streamline) in Hawaiian *Chelonia* as suspected (section 1.1), then a greater expenditure of energy, and perhaps even slower swimming speeds, would be expected to occur in comparison to Atlantic and Caribbean *Chelonia* populations.

It is significant to note that adults from the main islands, as well as from Laysan, Lisianski and Pearl and Hermes Reef, have only been recorded

traveling from their respective segments of the Archipelago as far as French Frigate Shoals, and not beyond. This further supports the belief that Hawaiian *Chelonia* return to their same resident foraging area at the end of each breeding season. Although a homing instinct for the breeding grounds is widely recognized for *Chelonia* populations, far less attention has been given to the pronounced fixation which also appears to exist for the resident area (see Balazs 57, Hirth 266). It is also significant to note that, except for the weak juvenile found at Wake, none of the turtles tagged in the Hawaiian Archipelago have been recovered at any other location in the Pacific.

It is unknown if the low level of breeding that occurs at islands to the northwest of French Frigate Shoals involves nonmigratory residents of these areas or adults that have remigrated from other locations in the Archipelago. The occurrence of remigrations would suggest that these turtles are genetic remnants of what at one time may have been far larger breeding colonies. Such reproductive voyages could conceivably be taking place from resident areas anywhere in the Archipelago. This could even include French Frigate Shoals, where tagged adult females known to live in the area have never been recorded nesting at that location. Although migrations from French Frigate Shoals to other areas for breeding purposes would seem to be totally unnecessary, this form of cycle is taking place when adults travel from the breeding areas of Laysan, Lisianski and Pearl and Hermes Reef to reproduce at French Frigate Shoals. Another possible explanation to account for nesting at islands to the northwest of French Frigate Shoals is that some of the females are returning to their resident area from French Frigate Shoals with an unlaidd clutch or partial clutch of eggs. The presence of eggs in a female shortly after her return to Kauai has been reported by a fisherman (tag 853 Table 1).

but details could not be obtained and no recent nestings have been recorded for this island.

It is unknown what motivating factors may have been involved in the 440 km movement of an adult female tagged while basking at Pearl and Hermes Reef in March 1965, and recovered while basking at Laysan in December 1967 (Kridler 324, Figure 10).

3.53 Navigation and orientation

The periodic migrations carried out in *Chelonia* populations between resident foraging areas and distant breeding grounds require some form of navigational ability. Furthermore, a highly refined guidance system would have to be in use for long distance movements involving small oceanic islands, such as from the coast of Brazil 2,000 km to Ascension Island (Carr 150, 151). Hirth (265) has suggested that navigation by green turtles is likely to be a composite process employing different senses that are based on a multiplicity of cues. The various mechanisms thus far suggested to explain this ability have also been summarized by Hirth (265), and include bicoordinate celestial navigation, light-compass sense, olfactory cues, perception of Coriolis force, magnetic sense, inertial guidance, sonar sense, and subtle oceanographic cues such as currents and wave patterns. However, the actual system or systems utilized remain totally unknown. This is mostly due to the unresolved problems of tracking a turtle over long distances of open ocean using boats, airplanes or land based monitoring techniques. The successful tracking of a turtle would reveal the actual routes taken, thereby aiding greatly in determining what cues are being employed. The recent availability of earth-orbiting satellites for wildlife telemetry offers considerable potential for answering this navigational question for a green turtle population.

A basic assumption in the migrations and navigation of *Chelonia* is that the adults return to breed at the same location where they originated as hatchlings. This fixation on the natal beach, which is supported by considerable indirect evidence, is thought to result from some form of "imprinting" that takes place when the hatchlings emerge from the nest or depart through adjacent waters. However, nothing is known about this process, if indeed one exists. If adults remigrate in groups to improve their accuracy of orientation, as has been suggested (Hirth 265), this could also serve the purpose of providing a learning mechanism for newly matured turtles to find their way back to the breeding grounds.

For Hawaiian *Chelonia*, the least complex system for finding French Frigate Shoals when remigrating from resident foraging areas would appear to be one in which the various islands and submerged areas with no emergent land are followed and used as navigational guideposts. Turtles residing in the main islands could follow the coastlines in a northwesterly direction, crossing the relatively narrow interisland channels of 15 to 120 km until reaching Kauai or Niihau. The next island guidepost could then be Nihoa (area 63 ha, elevation 273 m) located 225 km to the northwest, with a 19 fathom (35 m) shoal occurring at 125 km along this course. The distance from Nihoa to Necker (area 17 ha, elevation 85 m) is 295 km, but three small shoals are located at about the midpoint between the two islands. In addition, Necker itself is situated on a large 28 by 74 km bank with depths ranging from 8 to 23 fathoms (15-42 m). One of the few reported sightings in the Hawaiian Archipelago of a green turtle away from land was made in March 1979 along the southern edge of the Necker Bank. This involved an adult, but it could not be determined if the turtle was in transit or a resident of the area (G. L. Naftel personal communication). From Necker, the final goal of French Frigate Shoals for a remigrating turtle is 155 km directly to the west.

Turtles at resident foraging areas to the northwest of French Frigate Shoals would have to follow the Archipelago in a southeasterly direction during remigrations. Along this route the maximum span between an island and a submerged area, or two separate submerged areas, would be 155 km, the distance between Raita Bank and Gardner Pinnacles (area 1 ha, elevation 45 m). Between Pearl and Hermes Reef and French Frigate Shoals there are 14 submerged areas and three islands with associated banks. The largest of these is Gardner Pinnacles Bank which is 37 by 93 km, with depths of 10 to 25 fathoms (18-46 m).

Turtles traveling from resident foraging areas in the main islands to French Frigate Shoals would be moving generally with the prevailing currents and therefore would not be able to directly utilize chemical cues or plumes that may emanate from the various islands and submerged areas. Indirect use could result, however, by sensing the position of these areas once they have been passed and are upstream. Turtles traveling from the northwestern resident foraging areas to French Frigate Shoals would be moving generally against the prevailing currents and therefore could conceivably make direct use of chemical cues. During the return trip from French Frigate Shoals back to the resident areas, turtles from each segment of the Archipelago would be confronted with an opposite set of current conditions from their earlier voyage. Turtles returning to Pearl and Hermes Reef may benefit considerably from currents during certain years. A large log with two identifying numbers that washed off the beach at East Island sometime after 30 June 1979 was found at Pearl and Hermes Reef on 15 July 1979 (J. Koenig, personal communication).

In the latitudes of the main islands, the sun is at the zenith during late May as it travels to its farthest point north, and again in late July as it returns south. Turtles departing from French Frigate Shoals to return to

the main islands during July could therefore set a course each morning directly into the rising sun.

Another navigational aid that could possibly be used by Hawaiian *Chelonia* is the subtle color differences that are present in clouds due to reflections from shallower ocean depths where banks occur. However, the use of visual cues may not be essential considering that two males found with extensive fibropapillomas on their eyes were believed to have been recent migrants to French Frigate Shoals (section 3.34).

The evolution of reproductive migrations by *Chelonia* to mid-ocean Ascension Island is thought to be an adaptation to the gradual separation of South America and West Africa resulting from seafloor spreading (Carr 150, 151, Hirth 265). Similar geophysical mechanisms may also help to account for evolution of the Hawaiian *Chelonia* pattern with respect to voyages occurring between the geologically older northwestern areas of the Archipelago and the more recently formed French Frigate Shoals. This migratory component appears to be equivalent to the Ascension pattern. As new islands progressively appeared and disappeared, ancestors of Hawaiian *Chelonia* may also have gradually extended their traveling distances between resident foraging areas and aggregate breeding grounds. This theory does not, however, provide an explanation for reproductive migrations occurring from the main islands, which are known to be geologically younger than French Frigate Shoals.

While at French Frigate Shoals, nesting turtles demonstrate a distinct preference for a certain island and, to a lesser extent, show some favoritism for certain areas on that island (sections 3.15). The retention of this island fixity between breeding seasons in the 21 remigrations of females thus far

documented (section 3.16) suggests the presence of a refined memory system for short range orientation. Direct vision as well as olfactory cues are undoubtedly major components of this discrimination process. The orientation of turtles underwater at night prior to emergence for nesting could be expected to involve some of the same sensory cues used by turtles foraging at night in the resident areas (section 3.42).

3.6 Basking

Hawaiian green turtles exhibit the behavioral trait of coming ashore to bask or rest at certain undisturbed sites in the Northwestern Hawaiian Islands. This includes adults of both sexes and, to a lesser extent, immature turtles of all sizes larger than 35 cm. The land basking habit is rare among marine turtles, with Hawaiian and Galapagos *Chelonia* being the only two populations in which it has been well documented in the historical literature. However, basking in the Galapagos Archipelago has not been observed for a number of years and therefore may no longer be a characteristic of the population. There is no historical evidence of Hawaiian *Chelonia* basking on any of the main islands. However, an observation made at Johnston Atoll suggests that on rare occasions green turtles may bask at this location (Amerson and Shelton 31, Balazs 78). At the Wellesley Isles in Australia's Gulf of Carpentaria, female green turtles alone are known to come ashore during the breeding season to avoid males. The 27 December 1777 log of the *Resolution* states that at Christmas Island green turtles were turned on their backs while "asleep," and that this was a common method of capture (Beaglehole 105). In addition, previously unreported basking behavior by green turtles has been observed at Lizard Island on the Great Barrier Reef (W. Anderson and J. Leis, personal communications) and at North West Cape, Western Australia (J. Bradley, personal communication).

The presence of basking turtles in the Northwestern Hawaiian Islands was noted by many of the early visitors during the 1800's (Brooks 135, 136,

Farrell 220, Hornell 271, Lisiansky 335, Morrell 360, Munro 365-370, Paty 402, Read 429, Rothchild 435, Walker 531, Anonymous 564, 566). However, widespread knowledge of this behavior did not occur until publication of an account of the 1923 Tanager Expedition in a 1925 issue of *National Geographic Magazine* (Wetmore 542). A photograph from this article of a basking turtle at Lisianski was republished shortly thereafter in the *New York Zoological Society Bulletin* along with further descriptive information by Dr. Alexander Wetmore (Mellen 353). Several other authors subsequently mentioned the occurrence of basking by Hawaiian *Chelonia* as a rarity among marine turtles (Carr 150, 152, Grant 238, Loveridge 336, Pope 415). During aerial censuses of Hawaiian monk seals in 1957 and 1958, Kenyon and Rice (288) regularly observed turtles basking along the shorelines of the Northwestern Hawaiian Islands (see also Parsons 400). From 1950 to 1973, basking turtles were at various times recorded and counted in conjunction with biological surveys by the Pacific Ocean Fisheries Investigation (386-398), the Hawaii State Division of Fish and Game (Brock 133, Kramer 308, 309, Kramer and Beardley 310, Walker 532, 533, Woodside 554, Woodside and Kramer 555), the Pacific Ocean Biological Survey Program (see subject Index), and the U. S. Fish and Wildlife Service (Kridler 311-327, Olsen 380-385). Summaries of these observations and censuses have been published by Amerson (30), Amerson *et al.* (32), Clapp and Wirtz (171), Clapp and Kridler (172), Clapp *et al.* (173), Ely and Clapp (211) and Woodward (556). During recent years, photographs of basking Hawaiian *Chelonia* have appeared along with articles and reports by Altonn (6), Balazs (55 with *Monachus*, 57, 61 with *Ocyropsis*, 62, 78), Eliot (208), Hirth (265), Lipman (333), Moake (358 with *Chelonibia*), and Anonymous (642, 657, 667).

Basking in the Northwestern Hawaiian Islands takes place on calcareous sand beaches of varying particle size and composition located at French Frigate

Shoals, Laysan, Lisianski, Pearl and Hermes Reef, Kure and, on a single reported occasion, Midway (Balazs 78). At Laysan (P. and B. Johnson, personal communication) and Lisianski, some turtles also emerge on calcareous beachrock slabs. At Nihoa, two turtles have been seen on a single occasion basking on a rock at the base of the island's northwest cliff (Clapp *et al.* 173, Kridler 326). At Necker Island, basking turtles regularly use a small sloping rock ledge measuring approximately 4 by 5 m. During periods of large westerly and northwesterly ocean swells, some turtles bask at an alternate protected shoreline area a short distance away that is comprised of smooth waterworn boulders. The resident aggregation of green turtles that basks and feeds at Necker is undoubtedly one of the most interesting, unusual and fragile components of the Hawaiian *Chelonia* population (Balazs 72).

Although basking occurs principally in the daytime between approximately 1000 and 1830 h (variable with season), turtles at Necker have been found to also commonly emerge at night. At times this nocturnal emergence appears to be correlated with the setting of a bright moon (Balazs 72). The author has also observed small numbers of turtles resting along the shoreline at night at French Frigate Shoals and Laysan, but not at Lisianski. Amerman (24), Kridler (319) and Sibley (444, 445) frequently found turtles resting at night on Southeast Island at Pearl and Hermes Reef. Amerson *et al.* (32) attributed nighttime emergence to the disturbing activities of research personnel during the daytime. However, this seems unlikely in view of the fact that, for the September 1967 visit to Southeast Island by U. S. Fish and Wildlife personnel, Kridler (319) stated "When the island was first landed upon, there were no turtles present on the beach. At dusk the first day, however, one after another hauled up on the beach on the lagoon side near camp until 19 were present."

With the exception of La Perouse Pinnacle, basking occurs on all of the islands at French Frigate Shoals (Figure 2), as well as on several unnamed seasonally occurring sandbars. The northern shore of Trig Island and the northeastern shore of Whale-Skate Island are the most heavily utilized during all months of the year by the resident aggregation. At East Island, basking tends to coincide more with the breeding season (April-September). Turtles use the entire coastline, but higher concentrations consistently occur at the southeastern end (Figure 6, areas 8-9). As with nesting, turtles display a fixity for basking on a particular island and, to a lesser extent, for regularly basking at the same site on that island. The greatest numbers of basking turtles are found throughout French Frigate Shoals during late May and June due to the presence of the migratory breeding assemblage. The incidence of basking then declines as the breeding season progresses (Figure 11). The greatest number of basking turtles seen by the author at any one time was 52 (18 males, 18 females, 16 unknown) along the northeastern shore of Whale-Skate on 12 June 1978 at 1630 h. It is of interest to note that turtles have never been observed entering into nesting activity directly from a basking position.

Some adult Hawaiian *Chelonia* apparently do not bask. During each breeding season at French Frigate Shoals since 1973, approximately 46% (range 32.7-56.2%) of the turtles identified with painted numbers on their carapace while nesting were subsequently never seen basking. Some of these females are undoubtedly among the 40% that only lay a single clutch of eggs in a breeding season (section 3.15). Consequently, after nesting the turtles may not be present to bask because they have either departed on the return trip to their resident area, or have been eliminated by tiger sharks. Females that attempt to nest but do not lay eggs and are subsequently not seen again (section 3.15) also constitute some of the

turtles that are not seen basking. It is possible, however, that turtles in both of these categories do bask, but only during the time prior to first coming ashore to nest or make nesting attempts.

No differences were found between the lengths of the interesting intervals of basking and nonbasking turtles observed during the 1974 and 1975 breeding seasons. This indicates that basking does not significantly hasten the *in vivo* development of eggs for oviposition as might be expected.

It is important to note that at least some members of the seasonal breeding aggregation that are from resident areas in the main islands do in fact bask while they are at French Frigate Shoals. This is a significant point in that the 54% recorded basking each season could conceivably consist of only those females from Laysan, Lisianski and Pearl and Hermes Reef where basking is a regular occurrence. Both males and females observed basking at French Frigate Shoals have been among the tagged turtles recovered in the main islands (Table 15). In addition, basking has been displayed at French Frigate Shoals by three turtles that were returned to the wild after extended periods in captive facilities where emergence for basking was not possible (Table 16).

Investigations of the thermal ecology of basking Hawaiian *Chelonia* are currently being conducted by Whittow and Balazs (549). Results of this work to date have shown that the surface temperature of the carapace measured with a radiometer can attain values as great as 42°C. The large areas of black pigmentation present in most adult Hawaiian *Chelonia* undoubtedly contribute to high surface temperatures during periods of intense solar radiation. The greatest internal body temperature recorded through the cloaca was 31.3°C at a time when the ambient seawater temperature was 26.3°C. Shortly after coming ashore to bask, some turtles open their mouth to a wide position and regurgitate small

amounts of liquid (see Anonymous 670 for photograph). This is probably a result of compression of the stomach due to the body weight pressing on the plastron while on land. Turtles exhibit very little activity while basking except for occasionally flipping sand on their carapace for thermoregulation (see Tinker 492 for photograph). They do not, however, seem to orient their position in relation to the sun. In males, the tail will frequently be curled close to the body rather than fully extended. The length of time spent basking appears to be inversely related to the black-globe temperature. Respiration patterns while basking have been found to consist of breath-holds averaging 3.6 minutes, followed by a single shallow breath.

Basking in freshwater turtles (and other poikilotherms) is principally a behavioral strategy to raise body temperature and accelerate metabolic processes such as digestion and growth. Other motivating factors or benefits that have been suggested include synthesis of Vitamin D from skin sterols (Pritchard and Greenhood 419), removal of epizoids through drying, and social interaction (Boyer 132). These factors could also be applicable to basking by Hawaiian green turtles.

With respect to socialization (Hirth 265), considerable gregarious behavior is displayed while basking at French Frigate Shoals, with turtles often in direct contact or even partially on top of one another (Balazs 57). This is, of course, consistent with the other life activities of *Chelonia* such as feeding together, breeding together in large aggregations, and probably even traveling together across the open ocean. Hawaiian monk seals sometimes show gregarious tendencies toward basking turtles, both at French Frigate Shoals and at Necker. This has involved seals of all sizes from young pups to adults. Mothers with newborn pups may, however, make aggressive gestures and vocalizations at turtles emerging to bask in the immediate shoreline area.

One of the advantages to Hawaiian *Chelonia* obtained from basking is the reduction in exposure to predation by tiger sharks. . In some cases, this could even be the motivating factor for basking (section 3.33). Emergence to land at night may be especially advantageous, considering that tiger sharks are believed to be principally nocturnal predators. Resting along the shoreline at night could, however, also be due to a scarcity of acceptable resting sites located underwater. A further advantage to resting on land would be the conservation of energy by not having to periodically swim to the surface for respiration.

Hawaiian *Chelonia* will bask under captive conditions if they are provided with a sloping area suitable for emergence (Balazs and Ross 88). Both Sea Life Park and the Kahala Hilton Hotel on Oahu have display facilities in which Hawaiian green turtles regularly bask. However, hawksbills and loggerheads in the same pool at Sea Life Park never exhibit this behavior. A subadult green turtle of Hawaiian origin at the Kewalo Marine Laboratory, University of Hawaii, also regularly basks on a wooden ramp installed in its concrete tank (Whittow and Balazs 549). There are no reports in the literature of green turtles from other populations basking in captivity. However, most facilities where marine turtles are maintained do not have sloping areas where emergence can occur.

The basking behavior of Hawaiian *Chelonia* could very well be an inherited characteristic that evolved as a protective mechanism against tiger sharks, and as a method for gaining body heat at locations where seawater temperatures were marginal. The mean temperature of 20.5°C in February at the northwestern end of the Archipelago (section 3.43) could constitute such an environment at the present time, and perhaps cooler ocean conditions prevailed during the early development of the population. The survival value of basking, however, declined significantly with the first arrival of humans in the Northwestern Hawaiian Islands in the late 1700's.

The extensive exploitation of turtles that subsequently took place can be attributed mostly to the basking behavior which provides accessibility for easy harvesting in the terrestrial environment.

In addition to the unique research opportunities for tagging (section 3.52) and depth recordings (section 3.15), the basking behavior of Hawaiian *Chelonia* offers considerable potential for investigations of hearing and vision on land under natural conditions. The author is particularly interested in the aspect of vision, due to the fact that green turtles are believed to be myopic when out of the water (see Hirth 265). This would appear to be an unusual evolutionary development considering that the turtle's eyes leave the water each time a breath is taken. Observations to date have indicated that Hawaiian *Chelonia* display considerable visual sensitivity while basking.

4. POPULATION

4.1 Structure

4.11 Sex ratio

The inability to distinguish immature males from females on the basis of external characteristics is a limiting factor in determining natural sex ratios in populations of *Chelonia* and other marine turtles. Observations at French Frigate Shoals during June of 1973, 1978 and 1979 on days when relatively large numbers of adult basking turtles were ashore revealed a sex ratio of 66% females and 34% males (range 50-81% females, 23-50% males). As the breeding season progresses, the percent of basking males has been found to decline considerably. Of the 33 basking adults tagged by Amerson (28) at French Frigate Shoals during May and June of 1967, 73% were females and 27% were males. During May of 1972, Olsen (382) tagged 52

basking adults at French Frigate Shoals, with the resulting sex ratio of 54% females and 46% males. These various counts at the breeding colony would, however, be biased if a differential exists in the levels of basking undertaken by each sex. For example, males might be less inclined to bask when sexually receptive females are in the surrounding waters. At the same time, females that have already laid their first clutch of eggs for the season may be more inclined to bask in order to avoid the attention of males. An additional complicating factor is the occurrence of shorter reproductive cycles in males (section 3.16). This would cause the breeding aggregation to be an unrepresentative sample of the adults present in the total population, with the bias in favor of males.

Observations of adults basking at other locations in the Northwestern Hawaiian Islands have resulted in the following sex ratios: Necker - 71% females, 29% males; Lisianski - 62% females, 38% males; Pearl and Hermes Reef - 60% females, 40% males.

In the main islands, 48 adult green turtles were reported to the Hawaii State Division of Fish and Game as being captured by fishermen for noncommercial purposes from 1974 to 1977. Approximately 52% were listed as females and 48% as males. However, it is unknown if these determinations were made on the basis of external characteristics, or an internal examination of the reproductive tract. The reports for each island are listed as follows: Hawaii - 4 females, 0 males; Maui - 3 females, 1 male; Lanai - 0 females, 1 male; Molokai - 0 females, 3 males; Kauai - 10 females, 7 males; Oahu - 8 females, 11 males. The reports on file with the Division of Fish and Game for turtles commercially captured prior to the prohibition of 1974 do not contain information on sex.

The underwater sampling of green turtles using Scuba along the Kau coastline from July to September of 1976 resulted in the capture of one adult

female, eight subadults and 29 juveniles. None of the subadults showed evidence of tail enlargement (Wright *et al.* 557). Subsequent samplings along this resident foraging area using Scuba, as well as large-mesh tangle nets, have resulted in the capture of five more adult females, nine subadults and 26 juveniles. One of the subadults showed initial signs of tail enlargement (Balazs 64, Kam and Balazs 286).

The greater number of adult females that appear to exist in the Hawaiian green turtle population is consistent with the limited data on sex ratios summarized by Hirth (265) for several other *Chelonia* populations. However, further investigations are necessary to determine if tail enlargement among some males may be occurring after an "adult" size has been reached. It is also plausible that mortality rates may be higher in males than in females (section 4.4).

4.12 Size composition

The size composition of Hawaiian *Chelonia* based on a sample of 77 turtles captured along the Kau coastline has been found to be 71.4% juveniles, 22.1% subadults and 6.5% adults. These values are generally in agreement with sightings of turtles made during underwater surveys at Kau and other areas in the main islands.

Estimations of the weight composition of turtles reported as being commercially captured in the main islands from 1948 to 1973 are presented in Table 17. These data were calculated from reports submitted each year that listed the number of turtles captured along with the total weight. The resulting yearly average weights range from 4.5 to 115.7 kg, with the overall averages for each island ranging from 38.8 kg for Hawaii to 50.0 kg for both Molokai and Oahu. The standard deviations for the yearly weights indicate that most of the

turtles captured were immature, since the minimum weight for an adult female is 68 kg (section 3.12).

Caldwell and Caldwell (148), quoted by Hirth (265), theorized that green turtle populations may consist of mostly larger turtles due to high mortality of the very young, rapid growth of those that survive, and long life after reaching maturity. This is not in agreement with the findings to date for Hawaiian *Chelonia*, where there is a preponderance of juveniles that grow at a relatively slow rate, and many of the adult females appear to be involved in only a single breeding season during the course of their lifetime.

4.2 Abundance and Density

Based on systematic tagging and monitoring during each breeding season since 1973, the approximate number of females nesting annually at French Frigate Shoals has been found to range from 94 in 1976 to 248 in 1978 (Figure 12). The mean annual number of females for this seven year period is 180. An estimated total of not more than 20 females nest annually at Laysan, Lisianski and Pearl and Hermes Reef.

Prior to 1973, the breeding colony at French Frigate Shoals was thought to be considerably larger due to inadequate data. Estimates for August of 1965 by personnel of the Pacific Ocean Biological Survey Program ranged from 650 to 1,300 adult females and males (Amerson 30). However, this was based on the short-term tagging of basking turtles, and the erroneous assumption that a large daily exchange of new turtles continuously takes place at each island throughout the breeding season. Using these values, Hendrickson (262), quoted by Amerson (30), incorrectly speculated that 650 to 1,300 different turtles would also be present in June, and twice as many would be present in July. The total

breeding assemblage was therefore placed at between 2,600 and 5,200 turtles. Hendrickson (262) further qualified these values by indicating, "While it is very important to state flatly that this estimate has little basis and is *not* to be trusted, one can at least say that it does not appear to conflict violently with any other available quantitative information."

An estimation of the former size of the breeding colony can be obtained from an account in June of 1891 which states that at East Island, formerly known as Turtle Island, hundreds of turtles were found basking on the beach, and ten times as many were seen in the water (Walker 531).

The density of turtles nesting on each of the islands at French Frigate Shoals is presently at a level where the destruction of previously laid egg clutches is negligible (section 3.17). However, if larger breeding aggregations formerly existed under the same terrestrial conditions, density-dependent nest destruction may have naturally regulated the population size (see Hirth 265). This could be a significant factor in the future, in that density-dependent nest destruction can also result from reductions in the amount of available nesting habitat at a time when the population size is constant. At French Frigate Shoals, available habitat was reduced in 1942 with the extensive modification of Tern Island and establishment of permanent facilities. The reduction of nesting habitat due apparently to natural causes has also been documented by the author at East Island. At this location the northeastern coastline has eroded at least 20 m into the vegetation zone since 1948.

Counts of basking turtles in the Northwestern Hawaiian Islands made since 1950 (section 3.6) provide some indication of relative abundance at these resident foraging areas (Table 18). However, considerable variation can exist in both the numbers ashore at any one time, and the daily exchange of different turtles. Systematic tagging and observations over a defined period are therefore

needed, particularly at Lisianski and Pearl and Hermes Reef, in order to adequately assess the present status of these aggregations. Reductions in the number of basking turtles have occurred within historical times at most of the Northwestern Hawaiian Islands, but particularly at Laysan (Ely and Clapp 211) and Lisianski (Clapp and Wirtz 171).

Underwater surveys with Scuba along the Kau coastline resulted in the sighting of approximately three turtles during each hour of diving time. The use of a large-mesh tangle net measuring 3.5 by 80 m resulted in the average capture of four turtles for each 14 hour sample period (Balazs 64, Kam and Balazs 286).

4.3 Reproduction Rates

The basic reproductive data for Hawaiian *Chelonia* that have been determined at French Frigate Shoals (sections 3.15, 4.2) include 1) 104 eggs in each clutch, 2) 1.8 egg clutches laid within a season by each female, 3) 70.8% emergence of hatchlings from each nest, and 4) 180 females nesting annually. Using these values, a mean annual production of 23,857 hatchlings would occur at French Frigate Shoals. Since the number of nesting females over the seven year study period ranged from 94 to 248, the range in production would be 12,459 to 32,869 hatchlings. If the same egg clutch size, number of egg clutches, and percent emergence of hatchlings are assumed for the 20 females using Laysan, Lisianski and Pearl and Hermes Reef, then 2,651 hatchlings would result from these locations. The mean annual production of green turtle hatchlings for all areas of the Hawaiian Archipelago would be 26,508.

4.4 Mortality

The known factors affecting the natural mortality of Hawaiian *Chelonia* have been presented in sections 2.22, 3.2, 3.33 and 3.34. Tiger sharks are almost

certainly the principal cause of mortality following the transition from the pelagic environment to residency in a coastal area. Although the actual mortality rates resulting from this predator are unknown, differences in the levels of predation almost certainly exist between resident foraging areas. The percent of tiger sharks containing turtles has been found to vary considerably between some locations in the Archipelago, with the range extending from 6.7 to 75% (Table 19). Furthermore, at resident foraging areas in the Northwestern Hawaiian Islands where slower growth occurs, comparatively higher mortality rates would be expected for juveniles due to the greater length of time they are exposed to tiger sharks as small turtles. This is assuming, of course, that at least some increase in protection from predation is afforded as a turtle grows larger. Of the turtles recovered from tiger sharks at French Frigate Shoals, 44% were adults and 59% were juveniles (Balazs 70, Taylor and Naftel 482). This may indicate that larger turtles are less susceptible to attack, or it could simply reflect a greater abundance of juveniles.

The shorter reproductive cycles of males could serve to increase the mortality rate for this sex. By undertaking more frequent remigrations to French Frigate Shoals, males would be spending more time than females in an area where the risk of shark attack appears to be greater. In addition, the males that usually surround a copulating pair are undoubtedly more vulnerable to attack due to their erratic behavior and preoccupation with courtship activities. These accompanying males may also be inadvertently serving as a buffer against shark attack for the copulating pair. The long distance remigration in itself may include certain hazards that increase mortality, such as disorientation in the open ocean and exposure to large predators not presently implicated with Hawaiian *Chelonia* (i.e. killer whales, *Orcinus orca*, and great white sharks, *Carcharodon carcharias*).

The minimum survival rate necessary to maintain the Hawaiian green turtle population at a stable level is one in which each female replaces herself with a female offspring that survives to lay fertile eggs during at least one breeding season. Assuming an equal sex ratio at the time of hatching, each adult female at French Frigate Shoals produces an average of 66 female hatchlings. If a female is only involved in one breeding season during her lifetime, then at least 1.5% of her female hatchlings would have to survive for the population to be stable. Some Hawaiian *Chelonia* are, however, involved in more than one breeding season. This would increase the number of female hatchlings produced, thereby lowering the percentage that must reach maturity. The survival rates and reproductive cycles of adult females after their first breeding season are only partially known at the present time (sections 3.16, 3.3). Due to the tagging effort thus far expended at French Frigate Shoals and other locations in the Hawaiian Archipelago, there is an excellent potential for acquiring this information within a five year period.

It should be emphasized that it is unknown if the Hawaiian green turtle population is stable at the present time. The number of females nesting annually since 1973 has fluctuated substantially, and no trends can presently be detected (Figure 12).

4.5 Recruitment

The known factors affecting recruitment in the Hawaiian green turtle population are presented in sections 2.22, 3.12, 3.33, 3.34, 3.43, 3.51, 4.3, 4.4 and 5. The three principal levels of this recruitment are 1) recruitment of hatchlings to the pelagic environment, 2) recruitment of juveniles to coastal foraging areas, and 3) recruitment of adult males and females to the breeding colony. The information acquired to date indicates that these processes are

occurring in a closed system within the Hawaiian Archipelago and its surrounding pelagic waters. There is no indication that recruitment to resident areas within the Hawaiian Archipelago is occurring by juveniles that originated from other *Chelonia* populations in the Pacific. With the possible exception of Johnston Atoll and Wake, there is also no indication that green turtles of Hawaiian origin are utilizing any resident foraging area outside of the Archipelago. However, the possibility that such interactions may exist should not be entirely excluded at the present time. As in all marine turtle populations, basic data need to be acquired on the pelagic segment of juvenile development.

5. EXPLOITATION

5.1 Historical Overview

The exploitation of green turtles for food was found to be part of the native culture when Captain James Cook rediscovered the Hawaiian Islands in 1778 (Beaglehole 105, Anonymous 659). This traditional usage undoubtedly started as early as A.D. 600 with the initial occupation of Hawaii by Polynesians from other Pacific areas. Under the strictly enforced Hawaiian "kapu" system that remained in effect until 1819, turtles could only be eaten by men who were nobility or priests (Kalakaua 285). Turtles were captured principally by hand while diving underwater, with spears or harpoons from shore, and with nets made of cord from the bark of the olona plant, *Touchardia latifolia* (Cobb 176) and ahu'awa plant, *Gynerus javanicus* (Buck 145). The beveled edge of a pleural bone from a turtle's carapace was often used to scrape this bark and extract the durable fibers (Malo 341, Stokes 471, TenBruggencate 484). Another method of capture involved the use of two 7 cm hooks lashed to a flat stone that was attached to a long line (Cobb 176 with illustration). This was apparently used to hook turtles both from shore, and while diving in areas where resting takes place

Except for references to Nihoa in chants and legends, native Hawaiians were apparently not aware of the northwestern segment of the Archipelago at the time of Captain Cook's arrival (Emory 212). Exploitation of turtles was therefore confined to the main islands, although at a much earlier date some turtles were probably taken by the small groups of Hawaiians (or other Polynesians) that occupied Nihoa and Necker. An unresolved aspect of the exploitation of turtles by Hawaiians is the island which they called Ka Moku Papapa. This was described to Captain Cook and his officers on several occasions in both 1778 and 1779 as a low sandy island that was sometimes visited to catch turtles and seabirds. Ka Moku Papapa was said to be located to the west-southwest of Kaula ($21^{\circ}39'N$, $160^{\circ}33'W$), which is a small rock island 35 km to the southwest of Niihau (Figure 1). From Kaula, where an overnight visit was usually made, the natives reported that they could "very easily paddle there in the course of the following day" (Beaglehole 105). On 16 and 17 March 1779 the *Discovery* searched for Ka Moku Papapa without success while departing from Hawaiian waters. Although no island has ever been found in this vicinity, a small shoal with a depth of 9 m is situated 6.5 km to the northwest of Kaula. In addition, an area of discolored water possibly representing a shoal was reported in 1955 at a site 35 km to the southwest of Kaula at $21^{\circ}28'N$, $160^{\circ}45'W$. Nevertheless, for the short period of time involved, and the absence of geological activity within this region of the Archipelago, it would not have been possible for an island to have settled into the ocean (G. A. MacDonald, personal communication).

The traditional controlled exploitation of turtles by Hawaiians gradually disappeared with the abolition of the kapu system, the influx of caucasians and other racial groups, and the discovery of the unexploited and uninhabited northwestern segment of the Archipelago. Numerous commercial

expeditions to the Northwestern Hawaiian Islands took place during the 1800's and early 1900's to exploit green turtles, seabirds, monk seals, sharks, and beche-de-mer (*Holothuria* spp.). Turtles were taken principally for meat, oil and, along with monk seals, for use as a superior shark bait. When the Japanese-chartered fishing vessel *Ada* visited these islands for five months in 1882, at least 410 turtles were taken off the beaches and from the adjacent waters (Hornell 271). Other commercial expeditions to the Northwestern Hawaiian Islands that involved the exploitation of turtles during this early period are described by Amerson (30), Amerson *et al.* (32), Clapp and Ely (170), Ely and Clapp (211), Farrell (220), Galtsoff (231), Kemble (287), Munro (365-370), Walker (531), Woodward (556) and Anonymous (569). In June of 1923, the Tanager Expedition found evidence that turtles had been recently killed at French Frigate Shoals (Wetmore 541). It is also of interest to note that a newspaper article in June of 1867 described the rare presence of turtle eggs in the Honolulu market that had been imported from the Northwestern Hawaiian Islands (Anonymous 565).

Another factor in the exploitation of Hawaiian *Chelonia* was the occurrence of shipwrecks. The survivors of vessels that struck reefs in the Northwestern Hawaiian Islands often had to depend on turtles and other marine and terrestrial animals for food sources (Clapp and Wirtz 171, Lisiansky 335, Read 429, Ward 538, Anonymous 566). The 30 stranded crewmembers of a whaling vessel wrecked at French Frigate Shoals in March of 1859 killed in excess of 100 turtles before being rescued (Amerson 30, Walker 531).

In 1909 all of the Northwestern Hawaiian Islands except Midway were declared a United States preserve for native birds known as the Hawaiian Islands Reservation. In 1936 Kure was removed from this Reservation for military purposes and later, in 1952, transferred to the Territory of Hawaii. In 1940 the remaining

areas of the Hawaiian Islands Reservation were redesignated as the Hawaiian Islands National Wildlife Refuge. However, until recent years this protected refuge status has not served as a significant deterrent to the exploitation of turtles. In 1946 a commercial fishing base was established by the Territory of Hawaii at French Frigate Shoals. Both turtles and fish were captured in the area and transported to Honolulu by small aircraft using the abandoned military landing strip on Tern Island. Turtle meat also became a main food source in the diets of the resident fishermen. One of the two fishing companies using this base estimated taking about 200 turtles from 1946 until they terminated operations in 1948 (L. K. Agard *in litt.* to Amerson 30). Over this period the fishermen noted a decline in the numbers of turtles. Amerson (30) speculated that this was more the result of human disturbance than actual killing, however such an interpretation seems unlikely. During the summer of 1959, turtles were again exploited on the islands at French Frigate Shoals by a commercial fishing company based in Honolulu (Pacific Ocean Fisheries Investigations 395, D. W. Strasburg, personal communication, J. J. Dirschel, personal communication).

Both the commercial and noncommercial exploitation of green turtles in the main islands proceeded with virtually no controls from the time of the 1819 abolition of the kapu system, until the adoption of a protective regulation by the Hawaii State Division of Fish and Game in May of 1974. During this period the hunting techniques increased in both efficiency and sophistication, and the hunting range expanded to nearly all coastal areas. This was due principally to the availability of outboard motors, motor vehicles, firearms, spearguns, inexpensive machine-made nets and, at a later date, Scuba equipment. In addition, the commercial demand for turtle meat and other Hawaiian seafoods increased considerably with the advent of large-scale tourism following statehood in 1959

(Balazs 48, Benson 115, Hendrickson 262, Smyser 448). Based on the available records, Hawaiian green turtles have apparently not been commercially exported since the turn of the century. However, such commerce with Japan was proposed as recently as 1973 (Borreca 128, Linder 332).

As a general index of potential exploitative pressures, it is of value to note that the resident human population of the main Hawaiian Islands was approximately 130,000 in 1831, 54,000 in 1876, and 770,000 in 1970. Since 1831 the distribution of the human population has changed from 23% on Oahu and 77% on the other main islands, to 82% on Oahu and 18% on the other main islands. In 1778 there were an estimated 200,000 to 300,000 Hawaiian inhabitants. In the Northwestern Hawaiian Islands, Midway was first colonized in 1902 by the Commercial Pacific Cable Company. As a United States territory, the atoll has been occupied continuously since that time under the jurisdiction of the Navy. In 1978 the resident population was reduced to approximately 400 from the former 2,200 where it had been maintained for a number of years. Kure has been continuously inhabited by approximately 20 personnel since the construction of a U. S. Coast Guard LORAN Station in 1960. At Laysan Island a small resident population existed from 1891 to 1910, primarily in conjunction with the mining of guano (Bryan 139-141, Ely and Clapp 211).

5.2 Commercial Catch Reports

Turtles captured in the Hawaiian Islands for commercial purposes have been periodically recorded under the category of "honu (turtle)" in conjunction with other fisheries statistics (see Subject Index). Except for the few rare cases where hawksbills and leatherbacks have been taken, these records are only known to involve green turtles.

Cobb (176) presents data showing that over a four year period at the turn of the century, from 168 to 258 turtles were inspected and sold annually in the Honolulu fish market (Table 20). The total weight recorded for the 184 turtles sold in 1900 was 1248 kg, which yields an average of 6.8 kg per turtle. This quantity therefore probably only represents the meat and other edible portions after butchering. Based on this reported weight, approximately 96% of the turtles were captured with spears and 4% with nets. Ice was not used in the Honolulu fish market or at markets on the other islands during this period due to the prohibitive cost. Spearing must therefore have been carried out in a manner that would allow the turtles to be kept alive until butchered and sold. For 1900, Cobb (176) also records the sale of 443 kg of turtle on Maui, 364 kg on Hawaii and 68 kg on Molokai, all of which were taken with spears. It is also of interest to note that 192 1-lb cans of green turtle were among the large quantities of fisheries products imported to the Hawaiian Islands during the year 1900.

Since at least 1944, commercial fishermen in the Hawaiian Islands have been required to be licensed and to file catch reports on all species sold. From 1944 to 1947, the amount of turtle reported annually by live weight under this system was as follows: 1944 - 18,007 kg (no reports for January and February, report missing for April); 1945 - 8,954 kg (report missing for April); 1946 - 3,717 kg (no reports for June, July and August); 1947 - 4,317 kg. Table 21 presents the amount of turtle reported annually by various methods of capture for the years 1948 to 1973. These data fluctuate considerably, with annual amounts ranging from 173 kg in 1963 to 11,628 kg in 1972. A total of 90,803 kg was reported during the 26 year period. Due to the absence of a verification system, under-reporting and nonreporting undoubtedly had a significant influence on these values (Hendrickson 262). On Kauai, no reports for turtles were filed

from 1957 to 1969 (Table 17). In 1973 only 182 kg were reported for this island. However, information communicated to the author by a knowledgeable source indicated that approximately 4,500 kg of turtle were purchased from fishermen by a single tourist-oriented restaurant on Kauai during that year. There was also an absence of any turtle reports for Oahu during the years 1957, 1960, 1961 and 1968, as well as in 14 of the 26 years for the island of Hawaii (Table 17).

The listing of the methods used in the capture operations was not well defined in the commercial reports. This resulted in a number of unclear categories that are subject to some interpretation (Table 21). In addition, prior to 1961 most of the reports did not specify the method of capture.

The most frequently reported capture method for all years was Nets (49.5%). The categories of Scuba (5.6%) and Dive (0.5%) probably involved turtles that were captured solely by hand, and therefore should be combined with the Hand (2.3%) category to give a total of 8.4%. The first reported use of Scuba for capturing turtles commercially was in 1958. The Noose (0.3%) and Handline (1.5%) methods are also probably synonymous. This involves placing a line around the flipper or neck of a turtle sleeping underwater. The turtle is then pulled to the surface by other fishermen waiting in a boat. The Spear (3.4%) category, which was reported mostly after 1964, could include spearguns used while diving, as well as spears or harpoons thrown from a boat or from shore. The Gaff (10.2%) category reported exclusively after 1968, along with the Hook and Line (0.3%) category, are believed to involve variations of the earlier Hawaiian practice of catching turtles with a line attached to stone and two hooks (Cobb 176). One procedure incorporates a butcher's hook attached to a line that leads either to a boat where other fishermen are waiting, or to a free-floating buoy at the surface. The hook is then implanted into a large turtle found sleeping and

subsequently either pulled to the surface or allowed to swim until exhausted from towing the buoy. Another Gaff or Hook and Line technique is carried out from shore with barbed hooks cast into a lead weight that is attached to a pole and line. Working from coastal cliffs along foraging areas, turtles are then hooked in the flippers or neck when they swim within range. The single report listed under the category of Trolling (0.1%) probably involved an accidental snagging while trolling for fish. No information is currently available on the category designated as Trap (0.4%) which appeared in the records during 1962, 1963 and 1969. Possibly this involved the entry of turtles into large wire cages that are used by some fishermen to trap fish.

In addition to the methods presented in Table 21, the commercial capture of turtles is known to have included the illegal use of powerheads or underwater shark guns, as well as rifles used from shore in conjunction with a boat to retrieve the dead or wounded turtles.

Over the 26 year period, the greatest amount of turtle was reported for March (11.6%), and the least amount reported for November (4.8%) (Table 22). Figure 13 shows that the greatest amount of turtle was reported from Maui (37.1%), followed by Oahu (34.1%) and Molokai (17.6%). However, the absence of reports from Kauai and Hawaii during a number of years undoubtedly biased these percentages.

Along with catch data, commercial fishermen occasionally included informative observational notes in their reports to the Division of Fish and Game. A report filed for July 1968 recording the capture of 15 turtles in the area between Maui, Molokai and Lanai stated "This area in 1948-1950 I used to catch at least 100 in 4 to 5 days fishing- for some reason there are no turtles there now."

Some of the turtles commercially captured in the Northwestern Hawaiian Islands were reported to the Division of Fish and Game. These data are listed as follows. Pearl and Hermes Reef: 1953 - 161 kg, 1958 - 817 kg; Gardner Pinnacles: 1948 - 627-kg; Necker: 1951 - 690 kg; French Frigate Shoals: 1948 - 201 kg, 1950 - 531 kg, 1951 - 520 kg, 1953 - 730 kg, 1957 - 155 kg. Apparently no reports were filed for the 200 turtles taken commercially at French Frigate Shoals from 1946 to 1948, or the captures made in 1959 (section 5.1).

5.3 Noncommercial Catch

The noncommercial capture of green turtles in the Hawaiian Archipelago has resulted principally from sport and trophy hunting, and an esteem for turtles as food. The capture of turtles for true subsistence purposes has not been documented, but nevertheless may have occurred (and may still occur) in small numbers at some rural locations.

No records exist for the noncommercial capture of turtles prior to May of 1974. The annual amounts taken are therefore problematic but may have been substantial, particularly with the advent of Scuba equipment. The Director of the Division of Fish and Game, quoted in 1969 by Hendrickson (262), stated that "I have little doubt that the sport fishery take plus possible unlicensed commercial take far exceeds the legitimate commercial take." From May of 1974 to June of 1977, 48 adults and one juvenile (an illegal capture) were reported in compliance with the Division of Fish and Game regulation that permitted only noncommercial exploitation.

The methods used for the noncommercial capture of turtles are the same as those employed for commercial purposes (section 5.2 and Subject Index). Some recreational fishermen have also successfully taken turtles using a surf rod and reel with a baited hook (Carter 158). Another novel technique involved the use of a hunting bow with a line attached to an arrow (Anonymous 583).

The capture of Hawaiian *Chelonia* for noncommercial purposes was stimulated in 1975 with the publication of a popular book that described how to prepare sunburn lotion from green turtles (McBride 384). The potential risks of attack by tiger sharks resulting from use of such ointments before entering the ocean have been pointed out (Balazs 65).

Prior to 1977, green turtles at Midway were at times exploited for trophies and food by resident personnel. Similar captures were sporadically made by military personnel stationed at Kure and French Frigate Shoals.

6. PROTECTION AND MANAGEMENT

6.1 Regulatory Measures

Regulatory controls on the capture of Hawaiian *Chelonia* prior to May of 1974 included a ban on the use of firearms and, since 1949, a prohibition on the sale of turtles taken with spears (Territory of Hawaii 486, State of Hawaii 457, 458). Both of these measures also covered crustaceans, mollusks, aquatic mammals and fish (other than sharks). The prohibition on the sale of turtles taken with spears apparently was never enforced (Table 21).

In May of 1974, the adoption of Regulation 36 of the Division of Fish and Game banned the commercial exploitation of green turtles and the use of tangle nets. Adults measuring 36 inches (91 cm) and larger in straight carapace length could be taken for "home consumption," but only from waters around the eight main islands. The eggs and progeny of captive Hawaiian *Chelonia* could be sold under permit, along with green turtle products imported from any area outside of the Hawaiian Islands (State of Hawaii 465). This regulatory measure also gave full protection at the state level to the hawksbill and leatherback, which were already listed in the Endangered category under the U. S. Endangered Species Act.

The series of events surrounding the adoption of Regulation 36 are described in articles by Altonn (8, 9, 11, 12), Balazs (46-48), Benson (115,116), Chiaviello (160), Ching and McCabe (161), Kido (289-298), Moake (358, 359), Smyser (448, 449), Stansbury and Flattau (453), State of Hawaii (459-463), Stoffel (470) and Anonymous (594, 595, 597, 599, 600, 602-608, 610, 612, 618, 621, 622).

In September of 1978, Regulation 36 was superseded with the listing of Hawaiian *Chelonia* in the Threatened category under the U. S. Endangered Species Act (U. S. Department of Commerce 503, 504, Anonymous 668, 669). The population currently receives full protection through federal regulations issued along with this listing. Under an agreement formalized in July of 1977, the jurisdiction over all marine turtles subject to federal law is shared jointly by the National Marine Fisheries Service and the U. S. Fish and Wildlife Service.

4 In the Northwestern Hawaiian Islands, full protection for green turtles in the federally controlled Hawaiian Islands National Wildlife Refuge has at least theoretically been afforded since 1940. Although the exact refuge boundaries of each island-area have not always been clearly defined, as a minimum they encompassed all emergent land and the shoreline waters. It is relevant to note that in April of 1952 the Territory of Hawaii designated the Hawaiian Islands National Wildlife Refuge as a wildlife refuge under territorial law. However, according to this declaration (Resolution 7 of the Board of Commissioners of Agriculture and Forestry) this was only "...for management as a refuge for the mammal and bird wildlife found thereon....." Aspects of the disagreement between the state and federal governments over the refuge boundaries and the involvement of Hawaiian *Chelonia* appear in articles by Benson (113, 121-123), Conant (180, 181), Kakesako (284), Miller (356), U. S. Department of the Interior (524), Zalburg (563) and Anonymous (650).

The first known regulatory measure on the capture of Hawaiian *Chelonia* at Midway was issued by the U. S. Navy Station in 1969, and later formally incorporated into the area's wildlife management plan (U. S. Navy 528). Under this regulation, green turtles measuring 24 inches (61 cm) and larger in straight carapace length could be taken, but only by hand and not more than one per person each day. In 1975 this size restriction was increased to 36 inches, and in 1977 the turtles were afforded full protection.

Between 1973 and 1976, a number of Bills and Resolutions relating to the protection and research of Hawaiian *Chelonia* were introduced into the Hawaii State Legislature (see Subject Index). The only measure to eventually receive legislative approval was the appropriation of funds that has been used to partially support the author's present research program (King 305, Anonymous 642).

6.2 Management Practices and Options

6.21 Artificial stocking

There are currently no proven techniques for replenishing marine turtle populations through stocking or other artificial manipulations. However, in a number of populations the high level of predation on eggs and hatchlings warrants the use of experimental measures. This includes the transfer of eggs to protected areas for incubation and hatching, and the subsequent release of hatchlings under guarded conditions on the beach or a few kilometers offshore (Hirth 265, Parsons 400). Another experimental procedure is the "headstarting" or raising of hatchlings in captivity to a juvenile size where, presumably, less predation will occur when they are released into the wild.

The experimental stocking of Hawaiian *Chelonia* has thus far only been undertaken on a limited basis. In 1976, 295 of the 398 green turtle hatchlings that emerged from nests laid in captivity at Sea Life Park were released off Oahu as a

stocking effort. The propagation of these turtles was made possible by the construction in 1974 of an 8 by 15 m pool and adjacent sand beach to serve as a display and experimental breeding facility (Bourke *et al.* 131, Anonymous 636, 643). All of the green turtles in this pool (9 females, 3 males, 6 subadults) had been captured in the main islands at various unrecorded times since 1964. On four occasions eggs were recovered from the bottom of an earlier display pool in use at Sea Life Park, however incubation attempts were not successful. Mating activity was occasionally observed after the turtles were moved to the new facility in 1974, but nesting did not commence until June of 1976. Only four of the nine females were believed to have been involved in the nestings. Although some mating activity has occurred since 1976, additional egg laying has not yet resulted. Mating activity, as well as the deposition of eggs in display tanks lacking a sand beach, have also been periodically recorded in Hawaiian *Chelonia* at the Waikiki Aquarium (De Luca 193, Mowbray 362) and the Kahala Hilton Hotel (Daacon 192).

Twenty-four of the hatchlings that originated from Sea Life Park were subsequently raised in captivity for five months before being tagged and released off the western coast of Lanai (Bourke *et al.* 131). None of these turtles have thus far been recovered.

Between April of 1974 and August of 1977, a total of 54 juveniles 20 to 60 months of age were released off Oahu after being raised in captivity from hatchlings that were obtained at French Frigate Shoals (Altonn 5). Fourteen of these turtles have been recovered under contrasting circumstances. One turtle was found resting under a coral ledge along the Kau coastline, a minimum movement of 380 km from the release site (section 3.43). Another turtle traveled 110 km and was speared by a fisherman off the north shore of Lanai 11 months after being released. This was an interesting recovery since the turtle was observed with

several other *Chelonia*. However, when the fisherman's presence was detected, all of the naturally occurring turtles rapidly left the area. Other recoveries included two turtles found swimming close to shore in an erratic manner two days after release; one turtle tangled in a crab net two days after release, one turtle found on shore inside an enclosure used for porpoise six weeks after release; one turtle reported speared two weeks after release; and eight turtles found within 200 m of the release site over periods ranging up to four months after release.

In May of 1975, 26 other juveniles that had been raised in captivity from hatchlings were returned to French Frigate Shoals (Altonn 15). Five of these turtles have been recovered, with two individuals establishing a period of residency near Tern Island (section 3.43, Table 11). The other three recoveries were made four days after release, and included a turtle found crawling along the beach on Tern Island, a turtle found basking near an adult on Trig Island, and a turtle found swimming in shallow water adjacent to Whale-Skate Island.

A potential exists for increasing the number of live hatchlings at French Frigate Shoals by excavating nests after natural emergence has occurred in order to retrieve those individuals that did not reach the surface. Although 76.7% of the eggs laid in each nest at French Frigate Shoals produce live hatchlings, only 70.8% result in live hatchlings reaching the surface (section 3.15, Table 7). The remaining 5.9%, or an annual average of 1,988 hatchlings, result in mortality. Many of these hatchlings can be salvaged in an apparently healthy condition if they are excavated within a 3 to 5 day period.

6.22 Predator control

No measures have thus far been taken to reduce the number of ghost crabs at French Frigate Shoals in order to enhance the survival of hatchlings when they leave the nest and cross through the intertidal zone. Although predation is not

excessive compared to many other green turtle breeding areas, up to 1,200 hatchlings (5%) may be eliminated annually at French Frigate Shoals by these crustaceans (section 3.2). The small size of the islands would simplify the conduction of a limited control program.

Shark fishing programs have been carried out on several occasions in the main islands for the purpose of decreasing the risk of attack on humans, promoting shark meat as a food source, and for biological research. These intensive fishing programs were undoubtedly beneficial to Hawaiian *Chelonia* in view of the large number of tiger sharks eliminated. In the Northwestern Hawaiian Islands, the capture of tiger sharks has taken place at a reduced level in conjunction with predator-prey research of the monk seal (Taylor and Naftel 482) and, currently, as part of the trophic analysis of fish communities (Parrish and Taylor 399). While an intensive control program at French Frigate Shoals would result in immediate survival enhancement for green turtles, the possible long-term implications of such action would have to be carefully assessed. One possible adverse impact might be an increase in the number of small sharks after the large predators have been removed (Tester 487, Taylor and Naftel 482). This, in turn, could conceivably result in greater predation on hatchlings.

6.23 Enforcement and education

The enforcement of regulations protecting green turtles in the Hawaiian Archipelago is currently the responsibility of two agents with the U. S. Fish and Wildlife Service and two agents with the National Marine Fisheries Service. These personnel are based in Honolulu and are responsible for enforcing numerous other federal wildlife and fisheries regulations (Benson 110, Vernon 530). The Commanding Officer of the U. S. Navy Station at Midway also has enforcement responsibilities for the protection of Hawaiian *Chelonia* under his jurisdiction

(U. S. Navy 528). Unlike nearly all other green turtle populations, enforcement efforts with Hawaiian *Chelonia* are not complicated by international migrations. However, illegal exploitation is known to occur within the Archipelago, and the magnitude of this catch needs to be determined.

Since 1973 a number of magazine and newspaper articles, as well as lectures, have served to provide information to the general public about Hawaiian *Chelonia* (Baldwin 94, Balazs 44, 48, 55, 60, 62, Chong 162, 165, Eliot 208, Hendricks 261, Kim 299, Lipman 333, Sekora 439, Whitten 547, Anonymous 580, 608, 649, 660, 661, 663). In addition, the display facilities and educational programs at Sea Life Park and the Waikiki Aquarium have helped to generate interest in the biology and conservation of this population (Engle 215, Taylor 477-479, Anonymous 636).

6.24 Aquaculture

The intensive culture and breeding of Hawaiian *Chelonia* for conservation purposes, such as artificial stocking of hatchlings and headstarting experimentation, offer some potential as a management technique (section 6.21). However, this is likely to be an expensive undertaking unless carried out in conjunction with existing display facilities.

Periodic interest has been expressed in the commercial aquaculture of Hawaiian *Chelonia* as a source of marketable meat, curios and soup stock (Altonn 13, Benson 118, Borreca 129, Finnerty 221, Haugen 258, Mahikoa 340, Pryor 420-422, Anonymous 615). However, no operations were ever actually started. Investigations conducted by the author suggested that the commercial aquaculture of Hawaiian green turtles was neither biologically nor economically feasible under existing circumstances. Furthermore, such facilities were not considered to be in the conservation

interests of naturally occurring marine turtle populations (Altonn 15, Balazs 52, 58-60, 67, Benson 119, Ehrenfeld 206, Pfund 407). Under the present federal regulations, commerce in green turtle products is not permitted, and turtles cannot be acquired from the wild for use in commercial aquaculture facilities.

The only aquaculture of *Chelonia* known to have been carried out by the early Hawaiians involved a 15 by 150 m coastal pond on Oahu named Pahonu that was used to maintain turtles until they were ready to be eaten (McAllister 345, Whitten 544).

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Table 1. Number of *CheLonia* tagged throughout the Hawaiian Archipelago since 1973.

Location	Immature	Adult		Total
		male	female	
Kure Atoll	21			21
Midway Islands	65		1	66
Pearl and Hermes Reef		5	4	9
Lisianski	23	3	7	33
Laysan	1	1		2
Maro Reef				
Gardner Pinnacles				
French Frigate Shoals	130	122	483	735
Necker	7	4	6	17
Nihoa				
Kaula				
Niihau/Lēhua	4	2	5	11
Kauai	2			2
Oahu	75	2	6	83
Molokai				
Lanai	28	1	1	30
Kahoolawe				
Maui	1			1
Hawaii	87	0	5	92
Total	444	140	518	1102

Table 2. Straight carapace length and width of adult female green turtles at French Frigate Shoals.

Year	Straight Length			Straight Width		
	Mean (cm)	Range	N	Mean (cm)	Range	N
1973	92.5	83.3-103.4	52	72.1	62.2-86.4	51
1974	92.7	85.0-106.2	91	72.1	63.5-85.6	93
1975	91.7	84.3-102.4	113	70.9	64.3-78.7	115
1976	93.0	87.6-99.8	7	70.9	68.6-74.4	6
1977	89.9	80.8-100.3	36	71.4	59.9-75.9	36
1978	92.2	82.0-101.6	46	70.9	70.4-81.5	46
1979	93.7	88.4-102.9	34	71.6	63.5-78.2	32
Overall	92.2	80.8-106.2	379	71.4	59.9-86.4	379

Table 3. Curved carapace length and width of adult female green turtles at French Frigate Shoals.

Year	Curved Length			Curved Width		
	Mean (cm)	Range	N	Mean (cm)	Range	N
1973	97.3	88.1-107.9	44	90.7	80.0-102.1	44
1974	97.8	90.2-113.0	108	91.1	82.6-105.4	108
1975	96.3	85.1-108.0	135	90.9	80.0-102.1	135
1976	97.5	93.2-109.7	18	89.9	81.3-102.1	18
1977	97.5	91.2-106.7	37	90.9	81.8-97.8	37
1978	97.3	89.7-107.2	46	91.2	81.3-106.7	44
1979	99.1	92.7-108.5	27	92.2	83.8-101.0	26
Overall	97.3	85.1-113.0	415	91.2	80.0-106.7	412

Table 4. Summary of growth rates and projected years to maturity for green turtles sampled at resident foraging areas in the Hawaiian Archipelago.

Location	Growth rates cm per month*		Years to maturity (35-92 cm)		No. of growth measurements	Range of intervals in months
	Range	Mean	Range	Mean		
Main Islands						
Kau, Hawaii	.38-.52	.44	9-12	10.8	4	7-17
No. captures--79						
No. turtles---72						
Bellows, Oahu	.19-.21	.20	22-25	23.8	2	13-22
No. captures--24						
No. turtles---21						
Northwestern Islands						
Necker		.14		33.9	1	20
No. captures---9						
No. turtles----7						
French Frigate Shoals	.02-.13	.08	36-237	59.4	19	3-36
No. captures-214						
No. turtles--130						
Lisianski		.13		36.5	3	2
No. captures--30						
No. turtles---23						
Midway	.03-.21	.09	23-158	52.8	8	6-37
No. captures-293						
No. turtles--250						
Kure	.04-.12	.08	40-119	59.4	2	13-24
No. captures--23						
No. turtles---21						

* straight carapace length

Table 5. Number of egg clutches laid by green turtles at East Island, French Frigate Shoals.

No. of egg clutches	1974		1975		1974-1975	
	No. of turtles	%	No. of turtles	%	No. of turtles	%
0	13	12.1	7	7.0	20	9.6
1	31	28.7	53	53.0	84	40.4
2	20	18.5	34	34.0	54	26.0
3	26	24.1	6	6.0	32	15.4
4	12	11.1	0	0	12	5.7
5	5	4.6	0	0	5	2.4
6	1	0.9	0	0	1	0.5
Total	108	100.0	100	100.0	208	100.1
Mean	2.1		1.4		1.8	

Table 6. Internesting intervals of green turtles at East Island, French Frigate Shoals.

Interval in day	1974		1975		1974-1975	
	No. of intervals	%	No. of intervals	%	No. of intervals	%
11	6	8.0	1	6.7	7	7.9
12	17	23.0	4	26.7	21	23.6
13	26	35.1	2	13.3	28	31.5
14	13	17.6	5	33.3	18	20.2
15	8	10.8	2	13.3	10	11.2
16	2	2.7	1	6.7	3	3.4
17	1	1.4	0	0	1	1.1
18	1	1.4	0	0	1	1.1
Total	74	100.0	15	100.0	89	100.0
Mean	13.2 days		13.4 days		13.2 days	

Table 7. Results of 40 precounted egg clutches excavated and examined at East Island following the natural emergence of hatchlings.

	Mean	Standard deviation	Range
% of eggs hatched	76.7	24.2	0-100
% of hatchlings emerging at the surface	70.8	24.0	0-97.6
% dead hatchlings in the nest	5.9	9.4	0-52.1
% of eggs with partially developed but dead embryos	10.8	9.9	0-50.0
% of eggs with no apparent development (presumably infertile)	12.5	22.4	0-100

Table 8. Number of nesting green turtles tagged and subsequently recovered at East Island, French Frigate Shoals, 1973-1979.

Year	No. of tagging encounters	No. of tag recoveries						No. and % of tags thus far removed
		1	2	3	4	5	6	
1973	42							3(7.1)
1974	100							2(2.0)
1975	103		1					3(2.9)
1976	26		1	1				2(7.7)
1977	44			1				11(25.0)
1978	79		1	3				
1979	62		11	1			1	
Total	456		14	6			1	21(4.6)

Table 9. Food sources recorded for green turtles in the Hawaiian Archipelago.

Location	Principal constituents	Other food sources
Hawaii	R* - <i>Pterocladia capillacea</i>	<i>Amansia glomerata</i>
Maui	R - <i>Pterocladia capillacea</i>	
Kahoolawe	?	R - <i>Gelidium</i> sp.
Lanai	R - <i>Amansia glomerata</i> <i>Acanthophora spicifera</i> B - <i>Sargassum polyphyllum</i>	R - <i>Hypnea cervicornis</i> <i>Champia parvula</i> <i>Leveillea jungermannioides</i> <i>Gracilaria</i> sp. G - <i>Codium phasmaticum</i> B - <i>Dictyota acuteloba</i> <i>Padina japonica</i> A - <i>Halophila hawaiiiana</i>
Oahu	G - <i>Codium edule</i> <i>Codium arabicum</i> <i>Codium phasmaticum</i> <i>Ulva fasciata</i> <i>Ulva reticulata</i> R - <i>Pterocladia capillacea</i> <i>Amansia glomerata</i> <i>Ahnfeltia concinna</i>	R - <i>Gelidiella acerosa</i> <i>Gelidium pusillum</i> <i>Gracilaria coronopifolia</i> <i>Gracilaria bursapastoris</i> <i>Hypnea musciformis</i> <i>Hypnea chordacea</i> <i>Hypnea cervicornis</i> <i>Acanthophora spicifera</i> <i>Grateloupia filicina</i> G - <i>Caulerpa serrulata</i> <i>Caulerpa sertularioides</i> <i>Dictyosphaeria versluysii</i> <i>Enteromorpha</i> sp. <i>Cladophora fascicularis</i> B - <i>Dictyota acuteloba</i> <i>Padina japonica</i> BG - <i>Lyngbya majuscula</i> A - <i>Halophila hawaiiiana</i> I - <i>Chondrosia chucalla</i> <i>Spongia oceanica</i> <i>Brachidontes crebristriatus</i>
Kauai	R - <i>Pterocladia capillacea</i>	
Necker	G - <i>Caulerpa racemosa</i>	G - <i>Halimeda discoidea</i> R - <i>Amansia glomerata</i> <i>Hypnea</i> sp.

Table 9 (continued)

Location	Principal constituents	Other food sources
French Frigate Shoals	G - <i>Codium arabicum</i> <i>Codium phasmaticum</i> <i>Codium edule</i> <i>Caulerpa racemosa</i> <i>Ulva fasciata</i> B - <i>Turbinaria ornata</i> R - <i>Spyridia filamentosa</i>	B - <i>Lobophora variegata</i> <i>Rosenvingea orientalis</i> <i>Sphacelaria tribuloides</i> <i>Roschera</i> sp. R - <i>Gracilaria</i> new species <i>Porolithon gardineri</i> <i>Ceramium</i> sp. <i>Polysiphonia</i> sp. <i>Liagora</i> sp. G - <i>Microdictyon setchellianum</i> <i>Chlorodesmis hildebrandtii</i> <i>Halimeda discoidea</i> BG - <i>Microcoleus lyngbyaceus</i> I - <i>Physalia physalis</i> <i>Cerithiidae</i> <i>Anthrozoa</i> D - <i>Asterionella notata</i>
Laysan	?	R - <i>Spyridia filamentosa</i> <i>Amansia glomerata</i> G - <i>Microdictyon japonicum</i> <i>Pseudobryopsis oahuensis</i> <i>Halimeda discoidea</i> B - <i>Turbinaria ornata</i> <i>Padina crassa</i> <i>Zonaria variegata</i>
Lisianski	G - <i>Caulerpa racemosa</i> B - <i>Turbinaria ornata</i>	R - <i>Gelidiopsis</i> sp. <i>Pterocladia capillacea</i> <i>Jania capillacea</i> <i>Polysiphonia</i> sp. G - <i>Halimeda discoidea</i> <i>Chlorella</i> sp. BG - <i>Lyngbya majuscula</i> <i>Oscillatoria</i> sp. I - <i>Velella velella</i> <i>Janthina exigua</i> D - <i>Melosira</i> sp.

Table 9 (continued)

Location	Principal constituents	Other food sources
Midway	G - <i>Codium edule</i> R - <i>Spyridia filamentosa</i>	G - <i>Codium coneatum</i> <i>Caulerpa serrulata</i> <i>Caulerpa sertuarioides</i> <i>Dictyosphaeria versluysii</i> R - <i>Amansia glomerata</i> <i>Ceramium</i> sp. <i>Falkenbergia</i> sp. B - <i>Sphacelaria tribuloides</i> <i>Padina</i> sp. BG - <i>Lyngbya majuscula</i> <i>Oscillatoria</i> sp. A - <i>Halophila hawaiiiana</i> I - <i>Physalia physalis</i> <i>Velella velella</i> <i>Janthina exigua</i> <i>Echinoidea</i>
Kure	G - <i>Codium edule</i>	R - <i>Polysiphonia tsudana</i> I - <i>Physalia physalis</i> <i>Janthina exigua</i> <i>Echinoidea</i>

- * R - red algae, Rhodophyta
 B - brown algae, Phaeophyta
 G - green algae, Chlorophyta
 BG - blue-green algae, Cyanophyta
 D - diatoms, Bacillariophyta
 A - angiosperm (seagrass)
 I - invertebrates

Algae identified by D. J. Russell and M. S. Doty; invertebrates identified by W. J. Cooke; seagrass identified by K. Bridges.

Table 10.-Major food sources of green turtles in the Hawaiian Archipelago.

Location	Benthic algae
Main Islands (sample size N=85)	R* - <i>Pterocladia capillacea</i> <i>Amansia glomerata</i>
Main Islands and Northwestern Hawaiian Islands	G - <i>Codium edule</i> <i>Codium arabicum</i> <i>Codium phasmaticum</i> <i>Ulva fasciata</i>
Northwestern Hawaiian Islands (sample size N=56)	G - <i>Caulepa racemosa</i> R - <i>Spyridia filamentosa</i> B - <i>Turbinaria ornata</i>

- * R - red algae, Rhodophyta
 G - green algae, Chlorophyta
 B - brown algae, Phaeophyta

Table 11. Growth rates of Hawaiian green turtles released from captivity and raised in captivity.

Tag. no.	Site released	Site recovered	Straight carapace length, cm		Interval in months	Growth rate in cm per month
			Initial	Recovery		
<i>Returned to the wild after extended periods in captivity</i>						
702	Oahu	FFS	67.9	73.0	28	.18
216FW	Niihau	FFS	97.8	97.8	14	0
<i>Raised in captivity from hatchlings and released</i>						
474	Oahu	Kau, Hawaii	42.5	42.5	11	0
1442*	FFS	FFS	45.7	51.4	8	.71
1414*	FFS	FFS	40.6	45.0	16	.28
<i>Raised in captivity from hatchlings</i>						
2056 (9/72)	at 19 months of age (1.82 cm/mo)		34.6	58.7	62	.39
2054 (8/72)	at 17 months of age (1.94 cm/mo)		33.0	48.9	63	.25
2053 (10/73)	at 17 months of age (1.94 cm/mo)		33.0	57.2	51	.47
2051 (9/74)	at 25 months of age (1.31 cm/mo)		32.7	47.3	32	.46

* regularly fed fish scraps by U. S. Coast Guard personnel on Tern Island

Table 12. Growth rates of adult green turtles recovered at French Frigate Shoals since June 1973.

Tag no.	Straight carapace length, cm		Interval in months	Growth rate in cm per month
	Initial	Recovery		
<i>Females</i>				
699FW, 642	94.9	95.3	60	.01
372FW, 641	89.5	90.2	35	.02
362FW, 648	92.1	95.3	35	.09
391FW, 779	94.6	97.8	47	.07
T60FW, 723	88.3	91.4	25	.12
976FW, 763	94.6	96.5	37	.05
655FW, 828	90.2	92.7	75	.03
959FW	95.3	94.0	49	-
650, 1075	95.3	94.0	24	-
1029, 2605	94.0	95.6	36	.04
1047, 2729	100.6	101.6	36	.03
958FW, 2787	97.0	98.1	73	.02
2235, 3145	90.8	91.8	24	.04
2209, 2210	89.8	90.8	24	.04
842, 2270	94.6	95.6	24	.04
2253, 3228	92.7	92.7	24	0
2268, 3257	90.8	91.8	24	.04
2255, 3266	90.2	90.5	24	.01
5016, 5018	90.5	92.7	25	.09
651, 3264	87.0	87.9	72	.01
<i>Male</i>				
747FW, 2616	81.3	82.6	64	.02
Mean	91.8			.04
range	81.3-100.6		24-75	.01-.12
				N=18

Table 13. Growth rates of Hawaiian green turtles captured from the wild and held for extended periods in captivity at Sea Life Park (diet—fresh frozen squid and fish).

Tag no.	Straight carapace lengths, cm			Interval in months		Growth rates in cm per month	
	1	2	3	1	2	1	2
<i>Immature</i>							
2057	69.2	70.8	80.0	9	13	.18	.71
2067	62.2	69.2	79.4	9	13	.78	.78
2014	63.5	68.6	79.1	9	37	.57	.28
2065	64.8	73.6		13		.68	
2071	76.8	84.8	89.2	13	24	.62	.18
2018	73.3	80.3	84.8	13	24	.54	.19
<i>Adult Females</i>							
2021	85.7	87.6		59		.03	
2013	86.4	86.7		59		.01	
684	94.6	95.6		35		.03	
2017	92.7	93.7		46		.02	
2062	85.1	86.0		46		.02	
<i>Adult Males</i>							
2015	78.1	78.7		59		.01	
2019	82.6	84.5		35		.05	
2069	78.7	79.7		46		.02	

Table 14. Movements of Hawaiian green turtles in the main islands after being held in captivity for extended periods.

Tag. no.	Straight carapace length, cm	Date released	Date recovered	Interval (months)	Location released	Location recovered	Ocean distance (km)	
<i>Waikiki Aquarium *</i>								
316	62.9	1-73	11-73	10	Waikiki, Oahu	Iloli, Molokai	80	killed by fisherman
308	67.9	1-73	1-74	13	Waikiki, Oahu	Hauula, Oahu	75	killed by fisherman
310	66.7	1-73	6-75	29	Waikiki, Oahu	Hana, Maui	175	killed by fisherman
218	91.4	3-73	12-73	8	Niihau	Palaoa, Lanai	360	released uninjured
<i>Sea Life Park</i>								
872	59.0	1-75	4-75	3	Makapuu, Oahu	Kailua, Oahu	15	moribund-cause unknown

* see Stafford 452, Anonymous 596, 598

Table 15. Locations and numbers of tag recoveries documenting long distance migrations by adult green turtles in the Hawaiian Archipelago (sources - Balazs 57 and unpublished data; Kridler 311-327, Olsen 380-385).

Tagging and recovery locations	Males	Females	Total
French Frigate Shoals to:			
Kauai	1	8	9
Oahu	2	9	11
Molokai	1	3	4
Maui	0	2	2
Hawaii	1	1	2
Lisianski	0	2	2
Pearl & Hermes Reef	1	3	4
Hawaii to:			
French Frigate Shoals	0	1	1
Oahu to:			
French Frigate Shoals	1	0	1
Niihau to:			
French Frigate Shoals	0	1	1
Lisianski to:			
French Frigate Shoals	0	4	4
Laysan to:			
French Frigate Shoals	0	1	1
Pearl & Hermes Reef to:			
French Frigate Shoals	3	7	10
Pearl & Hermes Reef to:			
Laysan	0	1	1
French Frigate Shoals to main islands	5	23	28
Main islands to French Frigate Shoals	1	2	3
Total	6	25	31
French Frigate Shoals to northwestern islands	1	5	6
Northwestern islands to French Frigate Shoals	3	12	15
Total	4	17	21

Table 16. Long distance migrations of adult Hawaiian green turtles recovered since June 1973.

Tag no.	Date tagged	Location tagged and status *	Location recovered # and status *	Interval years/months *	Date recovered
<i>Females</i>					
1048FG	13 March 1964	Pearl & Hermes-B	East, FFS-N	10-3	2 June 1974
440FW, 742	21 March 1967	Pearl & Hermes-B	Pearl & Hermes-B East, FFS-N	4-1 3-2	27 April 1971 30 June 1974
167FW, 794 795	26 September 1966	Pearl & Hermes-B	East, FFS-N	7-9	30 June 1974
883FW, 1291	April 1969	Pearl & Hermes-B	East, FFS-N	7-3	7 July 1976
132FW, 1303 1304	20 September 1966	Pearl & Hermes-B	Trig, FFS-B	5-3	10 July 1976
995FW	27 April 1971	Pearl & Hermes-B	Whale-Skate, FFS-B	5-3	10 July 1976
152FW, T209 1306	23 September 1966	Pearl & Hermes-B	Pearl & Hermes-B East, FFS-N	6-0 3-10	September 1972 10 July 1976
655FW, 758, 828	20 March 1968	Lisianski-B	East, FFS-N	6-3	4 June 1974
660FW, 1298 1299	20 March 1968	Lisianski-B	East, FFS East, FFS-N	3-2 5-2	16 May 1971 9 July 1976
362 FW, 648	10 July 1970	East, FFS-B	East, FFS-N Kailua Bay, Oahu-O	2-11 0-3	17 June 1973 12 September 1973
672	9 July 1973	East, FFS-N	Maalaea Bay, Maui-O	1-1	31 July 1974
853	15 July 1974	Whale-Skate, FFS-N	Princeville, Kauai-O	0-1	15 August 1974

Table 16. (continued)

Tag no.	Date tagged	Location tagged and status *	Location recovered and status *	Interval years/months	Date recovered
2229	27 June 1977	East, FFS-N	Hilo Bay, Hawaii-0	1-0	2 July 1978
T216FW, 816 818	24 March 1973	Niihau-RC	East, FFS-B,N	1-2	3 June 1974
702 (subadult)	6 December 1973	Makapuu, Oahu-RC	Whale-Skate, FFS-B Whale-Skate, FFS-B	2-1 0-3	16 January 1976 10 April 1976
5016, 5018	8 May 1977	Kau, Hawaii-0	East, FFS-N	2-1	28 June 1979
<i>Males</i>					
1060FG, 1272 2011	16 September 1964	Pearl & Hermes-B	East, FFS-B Pearl & Hermes-B	11-10 1-0	4 July 1976 July 1977
122FW, 2594	20 September 1966	Pearl & Hermes-B	East, FFS-B East, FFS-B	11-9 1-0	11 June 1978 18 June 1979
2411**	13 October 1977	Waikiki, Oahu-RC	East, FFS-B	0-8	11 June 1978

* FFS - French Frigate Shoals
 B - basking
 N - nesting
 O - offshore
 RC - release from captivity

** see Altonn 23, Taylor 477, 479

Table 17. Mean weights of turtles from the Hawaiian Islands reported as being commercially captured, 1948-1973.

Year	Hawaii				Maui			
	Mean weight, kg	SD	N	% kg with N	Mean weight, kg	SD	N	% kg with N
1948	none *	-	-	-	15.8	9.6	63	98.0
1949	none	-	-	-	31.3	23.1	113	96.9
1950	36.3	12.8	25	100	45.5	0	1	56.2
1951	40.8	19.9	3	100	none	-	-	-
1952	none	-	-	-	68.2	0	1	100
1953	90.9	0	1	100	90.9	0	1	100
1954	68.2	-	6	100	8.6	7.0	2	100
1955	none	-	-	-	21.7	2.4	7	100
1956	none	-	-	-	18.5	7.3	18	100
1957	none	-	-	-	16.1	2.7	10	100
1958	-	-	-	-	18.1	5.9	31	100
1959	16.8	-	5	100	45.5	-	2	40.0
1960	none	-	-	-	45.7	35.1	16	77.7
1961	none	-	-	-	92.3	21.4	3	100
1962	none	-	-	-	none	-	-	-
1963	none	-	-	-	-	-	-	-
1964	15	0	1	100	24.8	13.4	17	93.0
1965	none	-	-	-	27.3	-	2	100
1966	30.6	14.3	4	100	18.2	0	1	100
1967	none	-	-	-	34.7	20.3	7	94.9
1968	11.0	10.5	99	100	13.9	4.7	27	100
1969	48.4	25.5	16	100	55.1	23.6	63	99.5
1970	30.9	0	1	100	62.5	31.0	73	100
1971	37.5	1.7	23	90.3	65	31.4	87	87.9
1972	none	-	-	-	63.9	42.7	85	100
1973	none	-	-	-	56.7	25.8	42	-
			184			672		
Mean	38.8				40.9			
Range	11.0-90.9				8.6-92.3			

Table 17 (continued)

Year	Lanai			Molokai				
	Mean weight, kg	SD	N	% kg with N	Mean weight, kg	SD	N	% kg with N
1948	22.7	0	1	100	none	-	-	-
1949	none	-	-	-	none	-	-	-
1950	none	-	-	-	24.1	-	17	64.3
1951	none	-	-	-	-	-	-	-
1952	none	-	-	-	8.2	-	7	100
1953	none	-	-	-	30.2	4.0	22	47.8
1954	none	-	-	-	47.4	19.4	15	76.3
1955	none	-	-	-	66.4	22.5	56	89.1
1956	none	-	-	-	67.6	30.3	33	100
1957	none	-	-	-	none	-	-	-
1958	none	-	-	-	none	-	-	-
1959	none	-	-	-	none	-	-	-
1960	40.0	11.7	19	100	none	-	-	-
1961	45.5	0	1	100	none	-	-	-
1962	none	-	-	-	none	-	-	-
1963	none	-	-	-	none	-	-	-
1964	none	-	-	-	none	-	-	-
1965	none	-	-	-	none	-	-	-
1966	89.4	18.4	3	100	44.5	18.3	11	100
1967	48.9	3.3	20	100	-	-	-	-
1968	54.5	0	1	100	none	-	-	-
1969	22.7	4.0	3	100	68.2	0	1	-
1970	none	-	-	-	none	-	-	-
1971	43.2	35.4	2	100	95.5	-	8	-
1972	none	-	-	-	55.7	-	36	53.3
1973	none	-	-	-	42.1	20.4	33	-
			50	-			239	
Mean	45.9				50.0			
Range	22.7-89.4				8.2-95.5			

Table 17 (continued)

Year	Oahu			Kauai				
	Mean weight, kg	SD	N	% kg with N	Mean weight, kg	SD	N	% kg with N
1948	33.8	13.8	54	25.6	none	-	-	-
1949	37.2	8.0	43	44.9	-	-	-	-
1950	23.3	8.1	15	11.1	-	-	-	-
1951	61.4	9.9	3	24.3	none	-	-	-
1952	38.7	27.9	19	87.2	-	-	-	-
1953	-	-	-	-	none	-	-	-
1954	-	-	-	-	none	-	-	-
1955	45.7	19.4	4	54.5	22.5	7.0	9	100
1956	83.0	-	2	89.2	27	3.4	5	75.7
1957	none	-	-	-	none	-	-	-
1958	4.5	0	1	100	none	-	-	-
1959	-	-	-	-	none	-	-	-
1960	none	-	-	-	none	-	-	-
1961	none	-	-	-	none	-	-	-
1962	-	-	-	-	none	-	-	-
1963	-	-	-	-	none	-	-	-
1964	115.7	12.6	2	100	none	-	-	-
1965	104.5	0	1	74.2	none	-	-	-
1966	49.7	49.1	5	13.9	none	-	-	-
1967	-	-	-	-	none	-	-	-
1968	none	-	-	-	none	-	-	-
1969	22.7	-	3	30.1	none	-	-	-
1970	15.9	0	1	2.2	-	-	-	-
1971	44.9	38.9	8	100	40.4	13.3	4	41.5
1972	79.5	12.7	43	96.0	18.2	-	5	100
1973	39.8	33.7	96	-	90.9	-	2	-
			300				25	
Mean	50.0				39.8			
Range	4.5-115.7				18.2-90.9			

* no reports submitted for the year

Table 18. Maximum numbers of green turtles seen basking at one time during surveys in the Northwestern Hawaiian Islands since 1950.

Location	Number of basking turtles	Month-Year	Reference
Nihoa (23°06'N, 161°58'W)	2	September 1971	Kridler (326)
Necker (23°35'N, 164°42'W)	7	November 1977	Balazs, unpublished data
French Frigate Shoals (23°45'N, 166°10'W) (nonbreeding months)	22	February 1975	Balazs, unpublished data
Laysan (25°43'N, 171°44'W)	6	September 1966	Kridler (316)
Lisianski (26°02'N, 174°00'W)	13	March 1964	Clapp & Wirtz (171)
Pearl and Hermes Reef (27°55'N, 175°45'W)			
Southeast Island	50	September 1966	Kridler (316)
North Island	10-20	1957-58	Kenyon & Rice (288) personal communication to Parsons (400)
Little North Island	10-20	1957-58	"
Bird and Sand Islands	8	January 1962	A. F. Carr, personal communication to Amerson <i>et al.</i> (32)
Midway (28°13'N, 177°21'W)	1	May 1975 (only record)	J. Bradley, personal communication
Kure (28°25'N, 178°10'W)	1	January 1979	J. Stark, personal communication

Table 19. Tiger sharks, *Galeocerdo cuvier*, captured at locations in the Hawaiian Archipelago where turtles were found to be prey items. (Sources - A. Tester 487 and unpublished data; Taylor and Naftel 482).

Location		No. tiger sharks containing food	No. tiger sharks containing turtles	Percent tiger sharks containing turtles
Island	Coastline			
<i>Main Islands*</i>				
Hawaii	southwest	9	1	11.1
	northwest	14	2	14.3
Maui	southwest	9	1	11.1
	west	5	1	20.0
Oahu	northeast	24	3	12.5
	southeast	6	1	16.7
	south	32	5	15.6
Kauai	northeast	4	3	75.0
	southwest	18	2	11.1
Niihau	east	13	2	15.4
	west	15	1	6.7
<i>Northwestern Hawaiian Islands</i>				
French Frigate Shoals		16	5	31.2
Pearl and Hermes Reef		11	4	36.3

* 25 tiger sharks that contained food but not turtles were captured by Tester (487) at other locations in the main islands

Table 20. Monthly number of turtles sold in the Honolulu Fish Market, 1900, 1902-1904. (source - Cobb 176).

Month	1900		1902		1903		1904	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
January	-	-	6	3.1	6	3.6	9	3.5
February	6	3.2	7	3.6	9	5.4	-	-
March	4	2.2	19	9.8	10	6.0	9	3.5
April	12	6.5	24	12.4	18	10.7	14	5.4
May	11	6.0	13	6.7	26	15.5	24	9.3
June	23	12.5	15	7.7	29	17.3	11	4.3
July	71	38.6	14	7.2	19	11.3	8	3.1
August	16	8.7	34	17.5	11	6.5	4	1.5
September	14	7.6	23	11.9	10	5.9	82	31.8
October	2	1.1	22	11.3	13	7.7	24	9.3
November	19	10.3	11	5.7	7	4.2	35	13.6
December	6	3.3	6	3.1	10	5.9	38	14.7
Total	184	100	194	100	168	100	258	100

Table 21. Kilograms and percent of turtle from the Hawaiian Islands reported as being commercially captured by various fishing methods, 1948-1973 (compiled by G. H. Balazs, R. Chau and E. Corbin from data on file at the Hawaii State Fish and Game Division).

Year	Net	Gaff	Scuba	Spear	Hand	Dive
1948	1,821 (20.1%)			4 (.1%)		
1949	4,509 (63.2%)			27 (.4%)		
1950	4,462 (82.9%)					181 (3.3%)
1951	599 (25.6%)					
1952	689 (55.5%)					
1953	1,814 (42.2%)					
1954	445 (32.2%)					
1955	3,296 (65.2%)					
1956	1,226 (38.9%)					
1957	120 (38.1%)					
1958	59 (4.1%)		164 (11.2%)		130 (8.9%)	208 (14.3%)
1959	97 (30%)					
1960					59 (3.5%)	
1961					322 (100%)	

Table 21 (continued)

Year	Noose	Trap	Hook and Line	Trolling	Handline	Unknown	Yearly Total, kg.
1948			175 (1.9%)		1,362 (15%)	5,699 (62.9%)	9,060
1949						2,601 (36.4%)	7,137
1950						741 (13.8%)	5,384
1951						1,740 (74.4%)	2,339
1952						552 (44.5%)	1,241
1953						2,489 (57.8%)	4,303
1954						937 (67.8%)	1,382
1955						1,760 (34.8%)	5,056
1956						1,923 (61.1%)	3,148
1957						196 (61.9%)	316
1958				76 (5.2%)		821 (56.3%)	1,458
1959						227 (70%)	324
1960						1,641 (96.5%)	1,699
1961							322

Table 21 (continued)

Year	Net	Gaff	Scuba	Spear	Hand	Dive
1962						
1963	102 (58.9%)					
1964	32 (4.3%)				332 (45.4%)	
1965	36 (5.3%)			545 (79.5%)		
1966	1,960 (83.4%)			268 (11.4%)		
1967	1,104 (48.4%)			1,175 (51.6%)		
1968	1,355 (88.9%)			54 (3.6%)		
1969	3,089 (66.8%)	227 (4.9%)	550 (11.9%)		662 (14.3%)	
1970	4,599 (80.9%)	423 (7.4%)		245 (4.3%)	190 (3.4%)	
1971	2,776 (30.7%)	4,605 (50.9%)	341 (3.8%)	620 (6.9%)	339 (3.7%)	52 (.6%)
1972	5,249 (45.1%)	3,181 (27.4%)	1,954 (16.8%)	115 (1%)	16 (.1%)	
1973	5,516 (63.4%)	866 (10%)	2,085 (24%)		27 (.3%)	
1948- 1973	44,955 (49.5%)	9,302 (10.2%)	5,094 (5.6%)	3,053 (3.4%)	2,077 (2.3%)	441 (.5%)

Table 21 (continued)

Year	Noose	Trap	Hook and Line	Trolling	Handline	Unknown	Yearly Total, kg
1962		217 (100%)					217
1963		71 (41.1%)					173
1964			45 (6.2%)			322 (44.1%)	731
1965						104 (15.2%)	685
1966			9 (.4%)			114 (4.8%)	2,351
1967							2,279
1968						114 (7.5%)	1,522
1969		97 (2.1%)					4,625
1970						227 (4%)	5,684
1971	161 (1.8%)					145 (1.6%)	9,037
1972						1,114 (9.6%)	11,628
1973	182 (2.1%)					19 (.2%)	8,695
1948- 1973	343 (.3%)	385 (.4%)	229 (.3%)	76 (.1%)	1,362 (1.5%)	23,486 (25.9%)	90,803

Table 22. Kilograms and percent of turtle from the Hawaiian Islands reported as being commercially captured by month, 1948-1973.

Month	Kilograms	Percent of total
January	8,950	9.9
February	7,729	8.5
March	10,524	11.6
April	8,977	9.9
May	6,900	7.6
June	8,477	9.3
July	7,680	8.5
August	7,682	8.5
September	7,298	8.0
October	6,073	6.7
November	4,312	4.8
December	6,201	6.8
Total	90,803	100.0

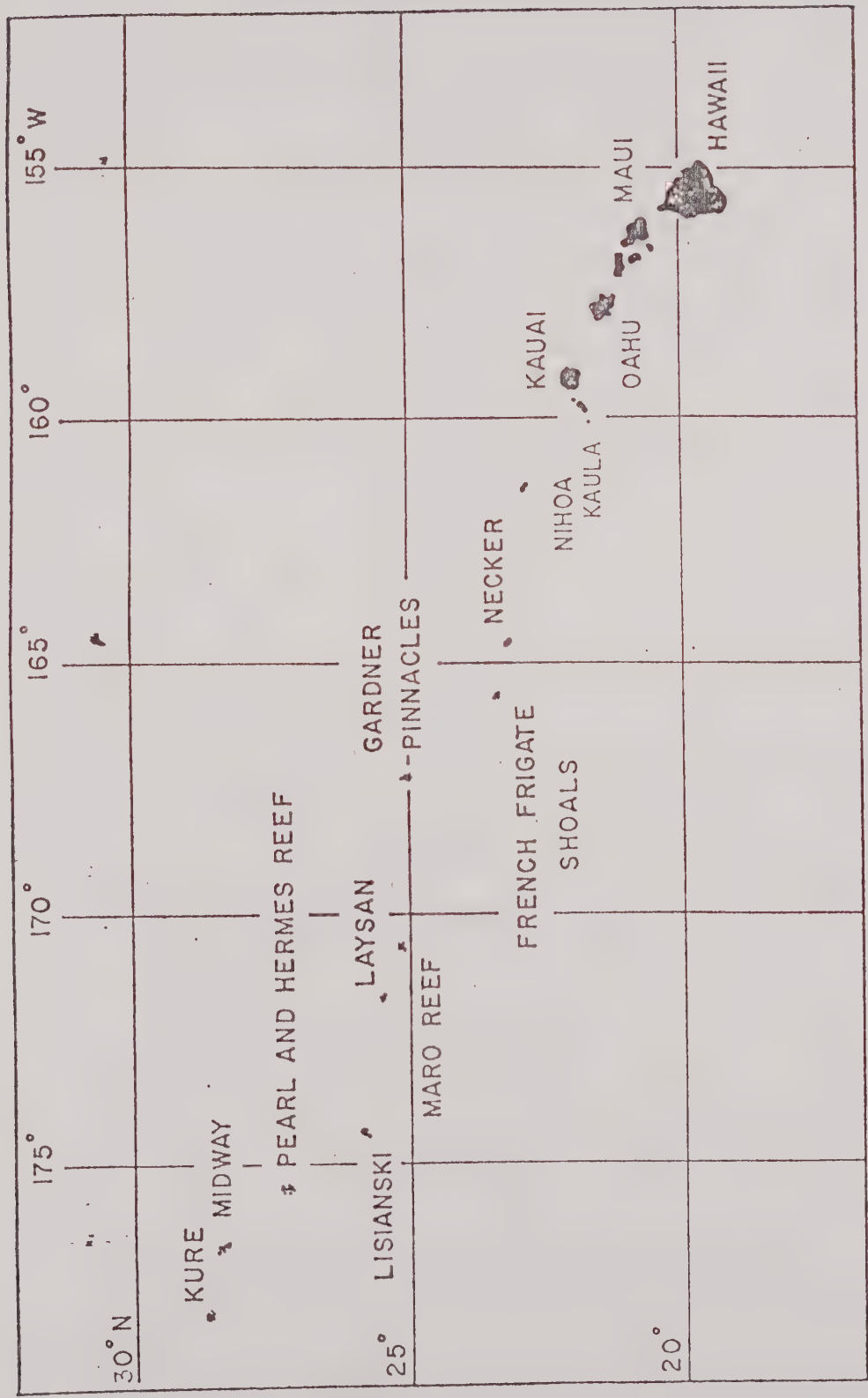


Figure 1.
HAWAIIAN ARCHIPELAGO
NORTH PACIFIC OCEAN

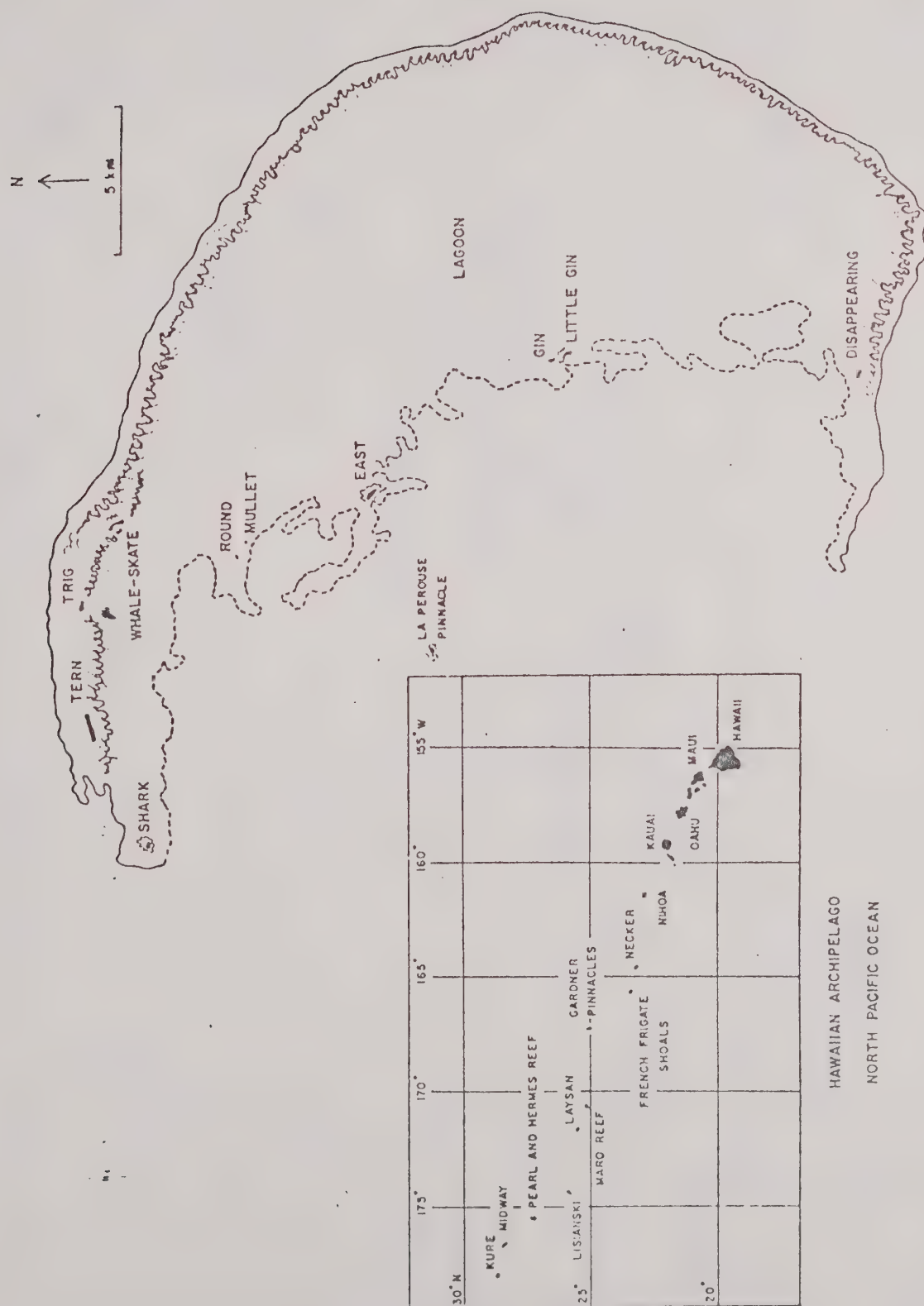


Figure 2. FRENCH FRIGATE SHOALS
23°45'N 166°10'W

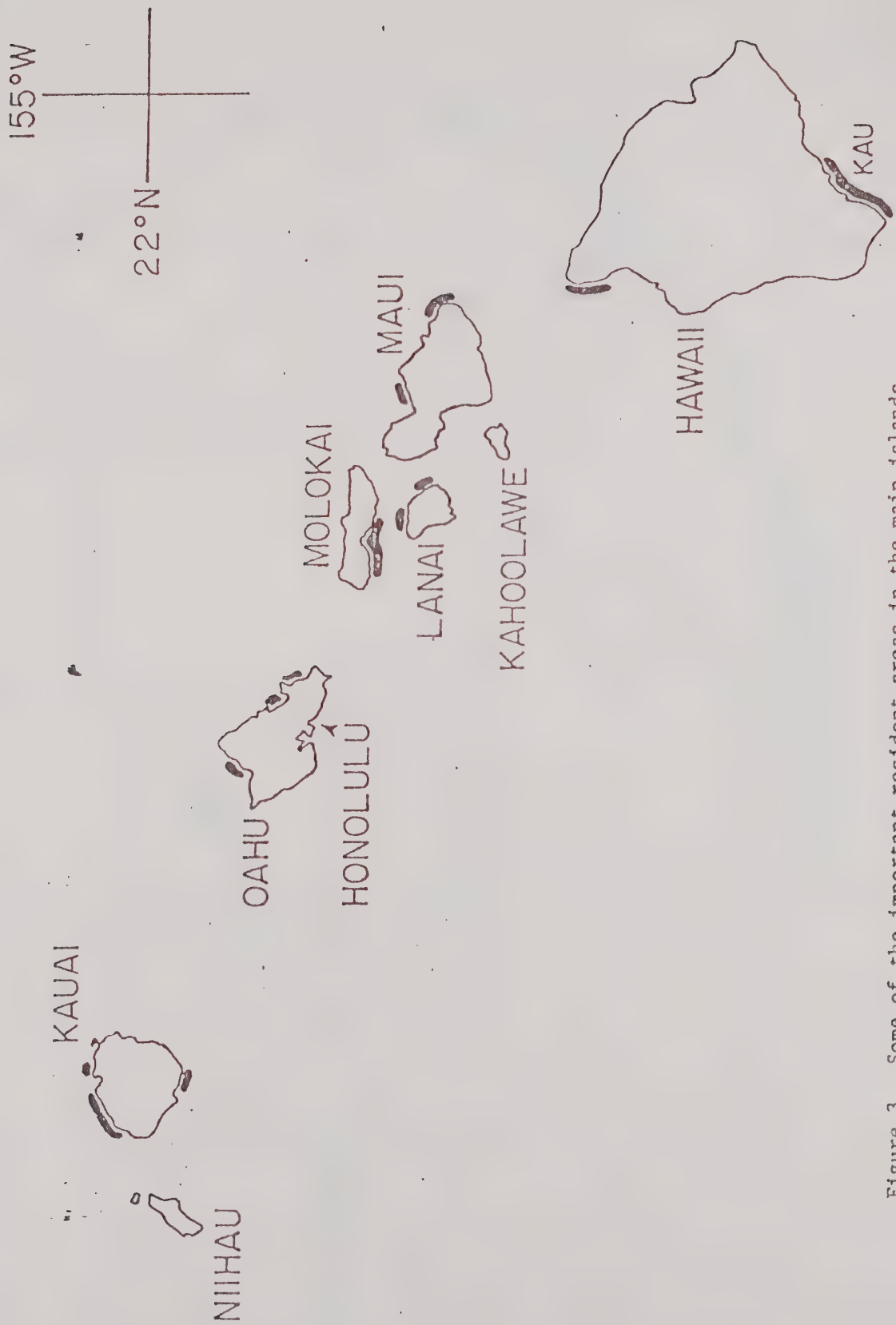


Figure 3. Some of the important resident areas in the main islands where Hawaiian green turtles feed and rest.

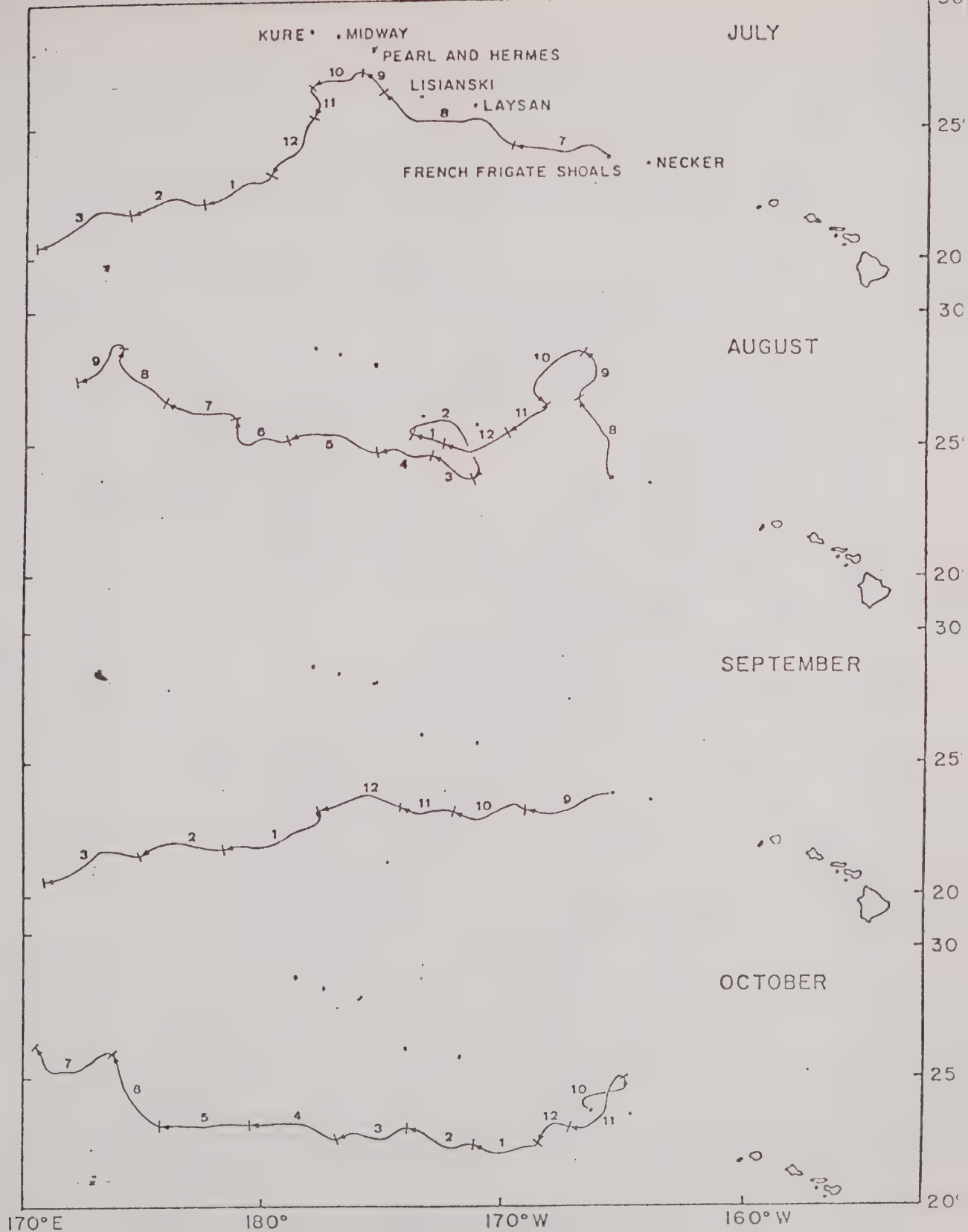


Figure 4. Surface drift trajectories representing the theoretical movement of hatchling and post-hatchling *Chelonia* leaving French Frigate Shoals. Segments of paths represent estimated distances covered during subsequent months. Most hatchlings emerge during August. (from Balazs 57, courtesy of R. Barkley, Honolulu Laboratory, National Marine Fisheries Service)

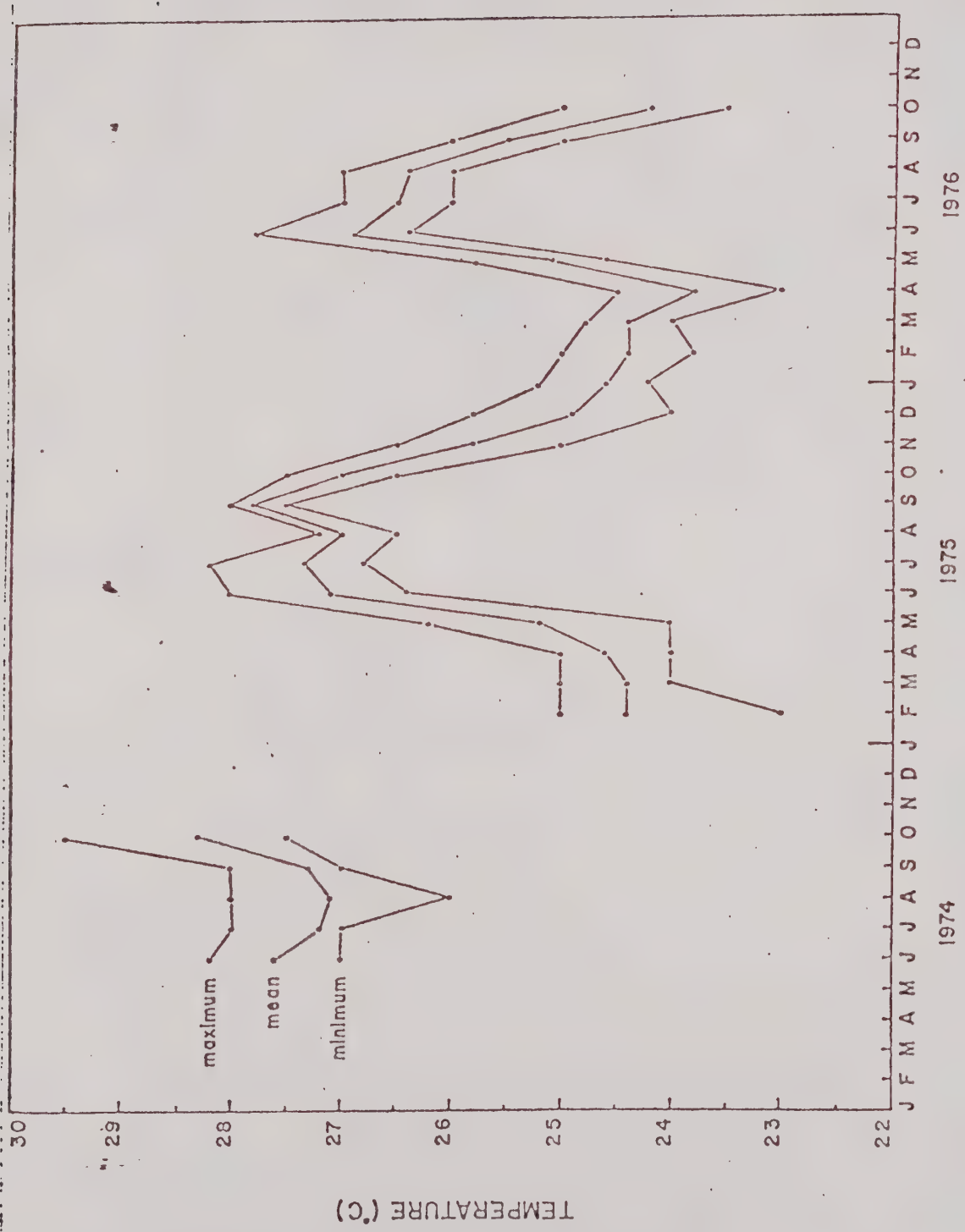


Figure 5. Sea surface temperatures at French Frigate Shoals. Data presented for each month represent an average of seven recordings. (Source - C. H. Balazs and U. S. Coast Guard personnel)

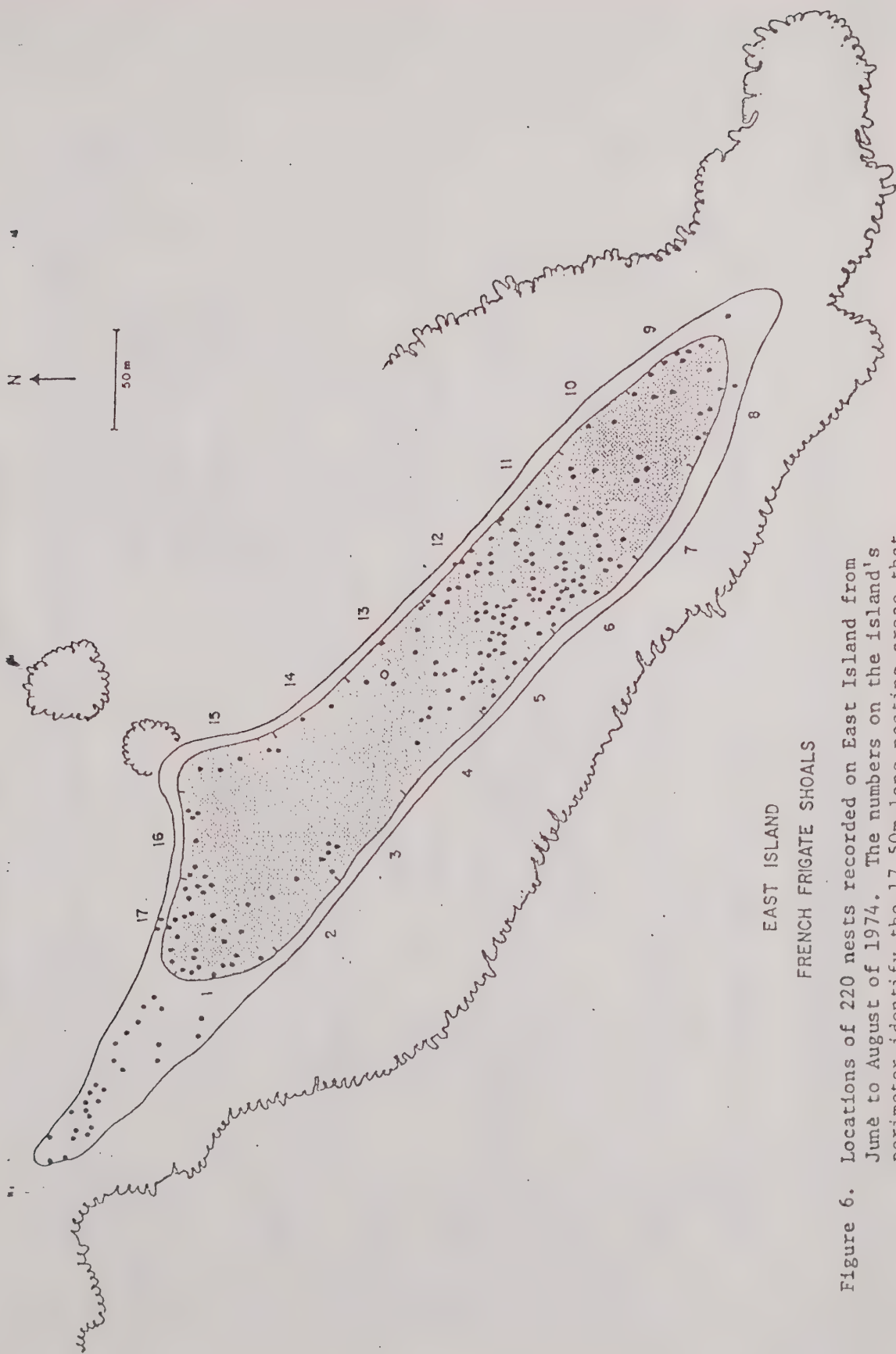


Figure 6. Locations of 220 nests recorded on East Island from June to August of 1974. The numbers on the island's perimeter identify the 17 50m-long nesting areas that have been established for use.

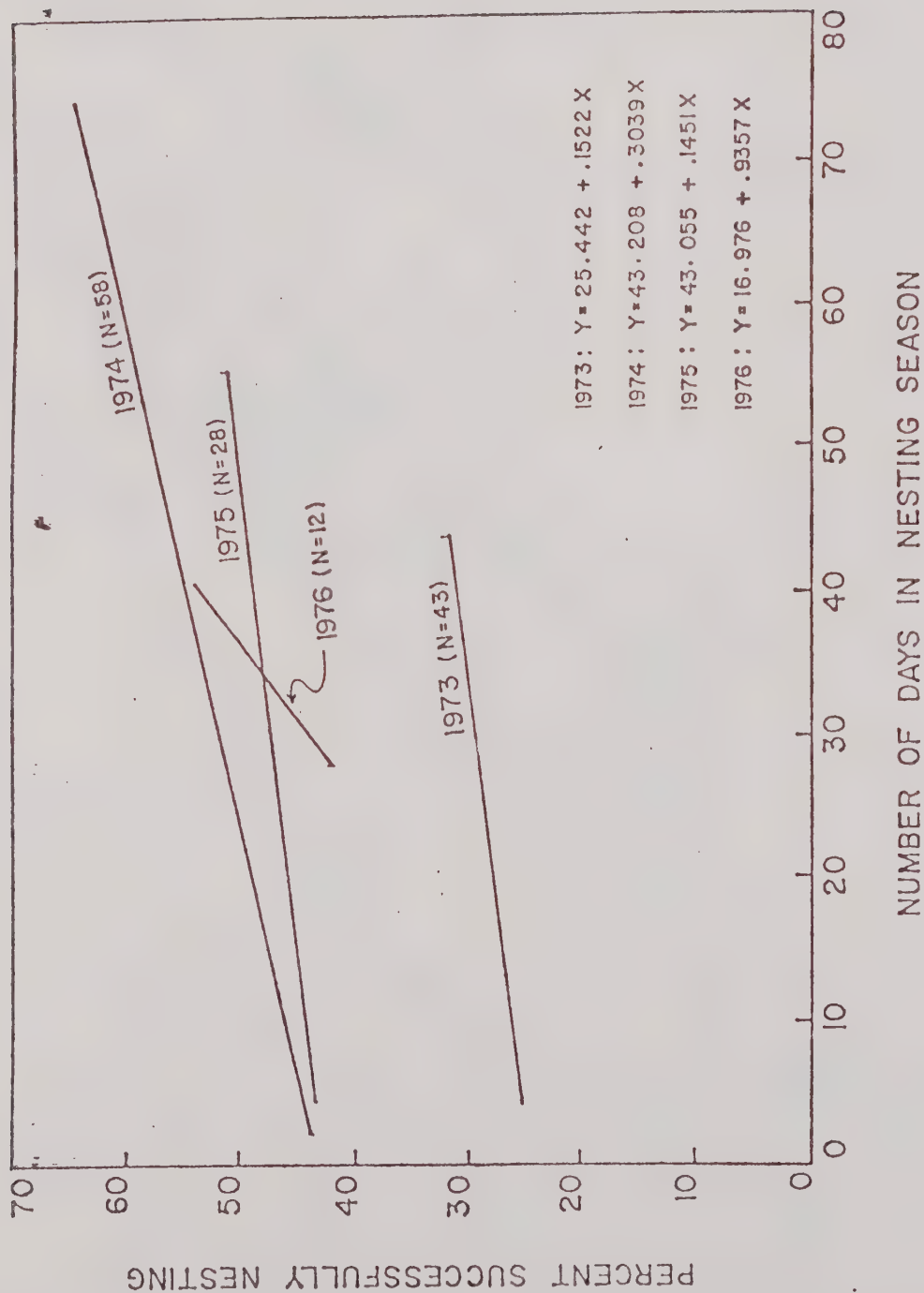


Figure 7. Percent of green turtles successfully nesting each night at East Island, French Frigate Shoals (day 1 = 1 June).

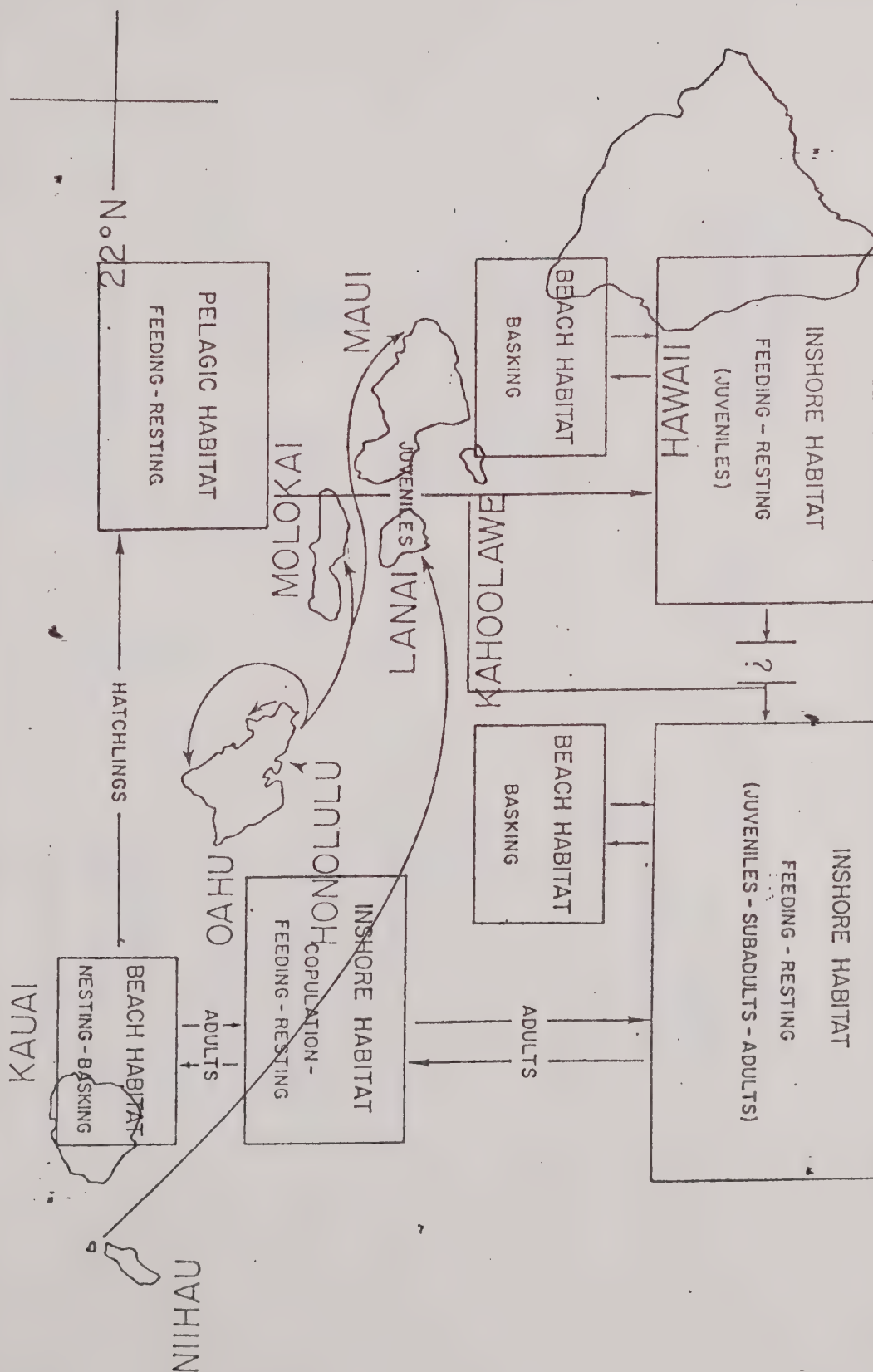


Figure 9. Life history and habitat model for Hawaiian *Chelonia* (adapted from Carr *et al.* 1953).

Figure 8. Tag recoveries of green turtles returned to captivity. The actual routes followed are unknown. The periods of dependence after release to the wild are unknown.

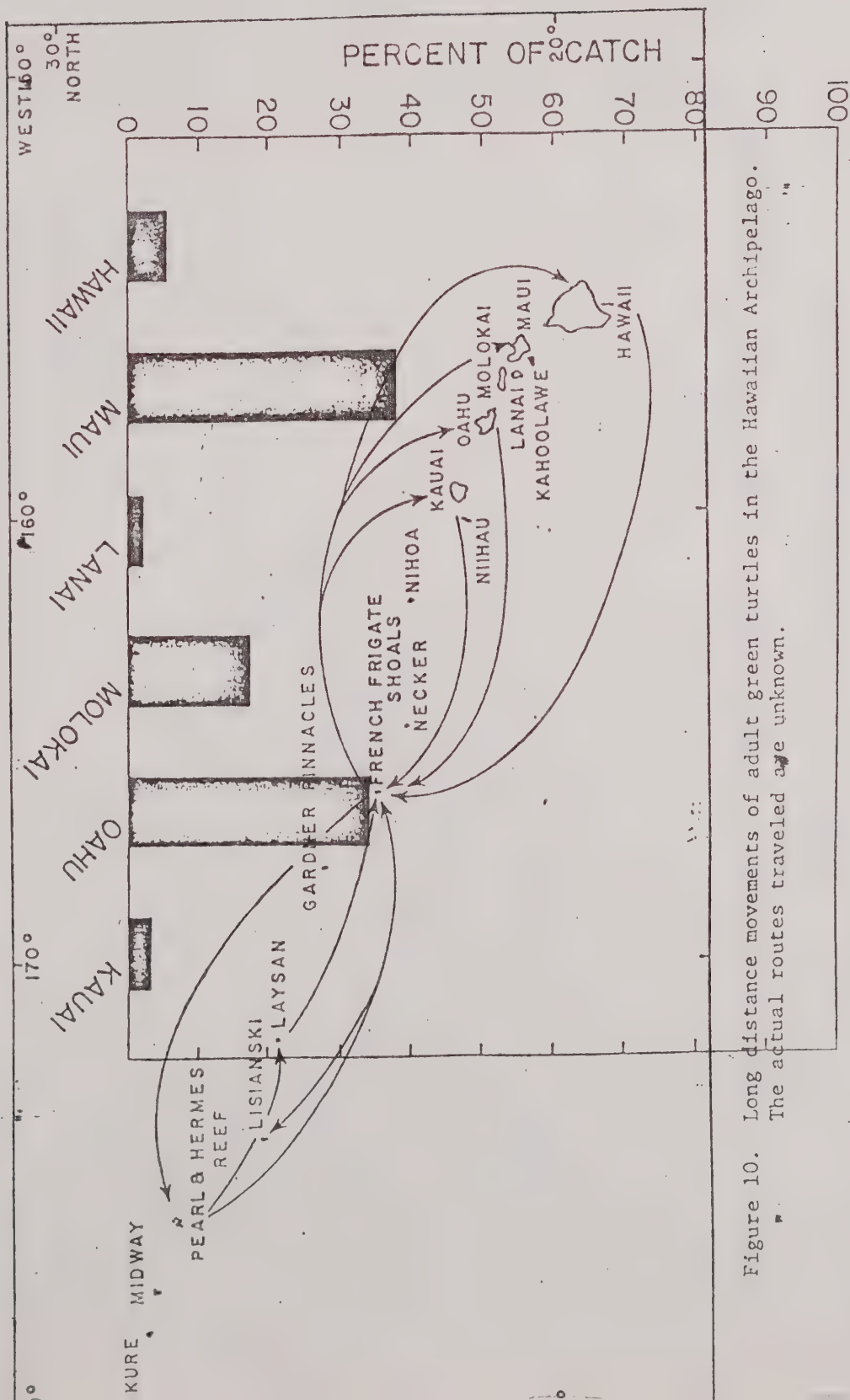


Figure 10. Long distance movements of adult green turtles in the Hawaiian Archipelago. The actual routes traveled are unknown.

Figure 13. Percent turtle reported as being commercially captured for each of the main islands, 1948-1973.

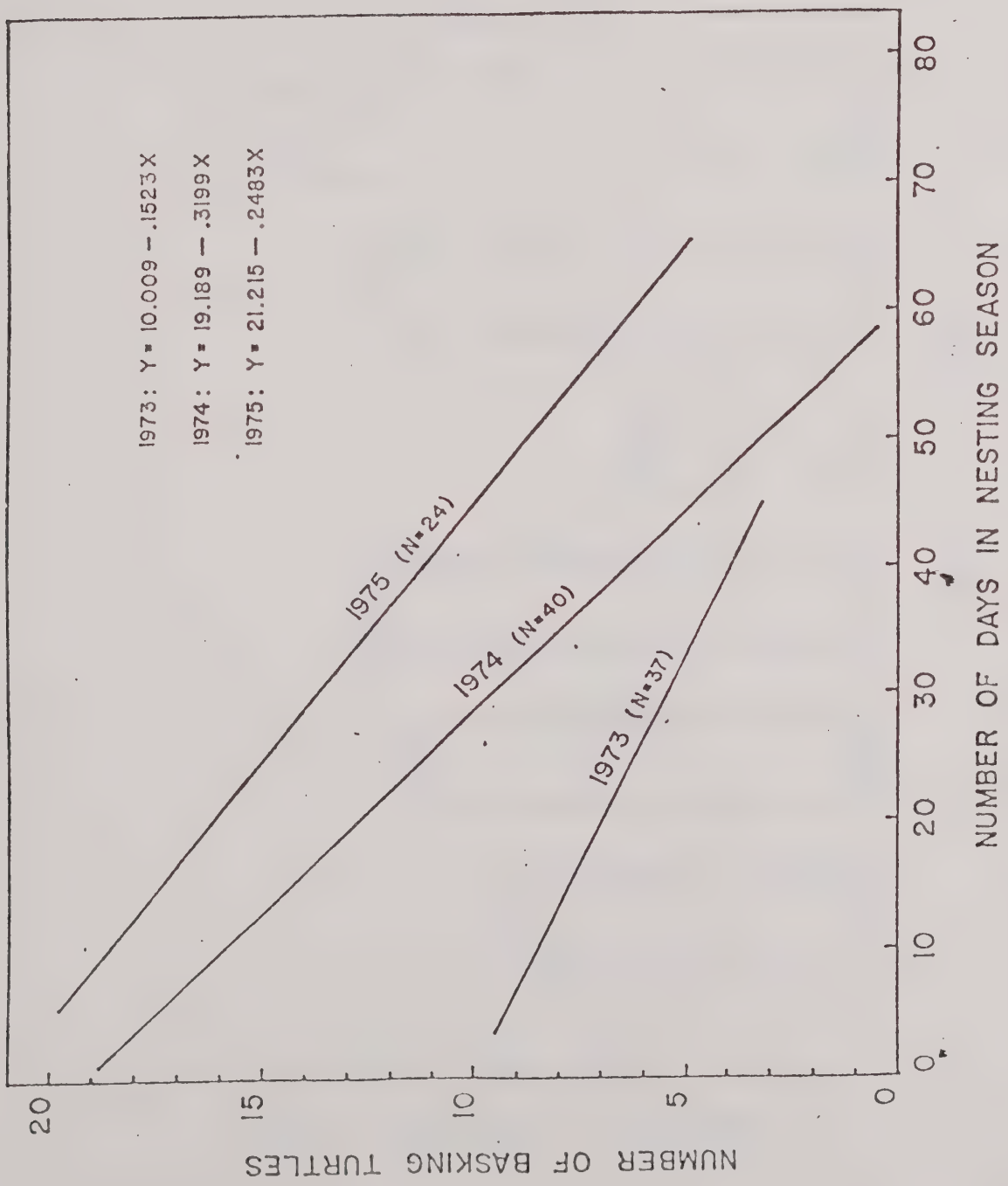


Figure 11. Incidence of daily basking at East Island, French Frigate Shoals (day 1 = 1 June).

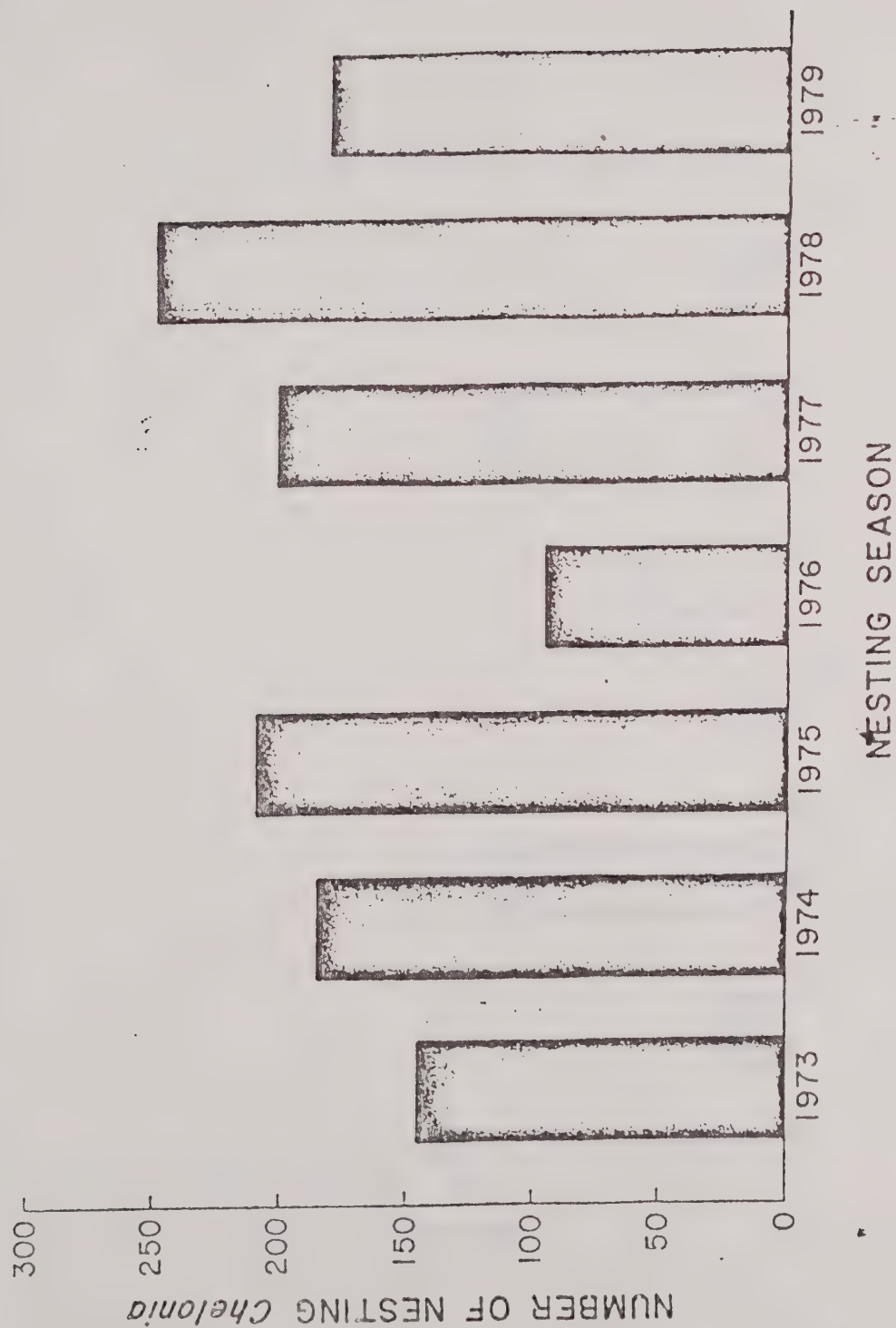


Figure 12. Number of females nesting annually at French Frigate Shoals.

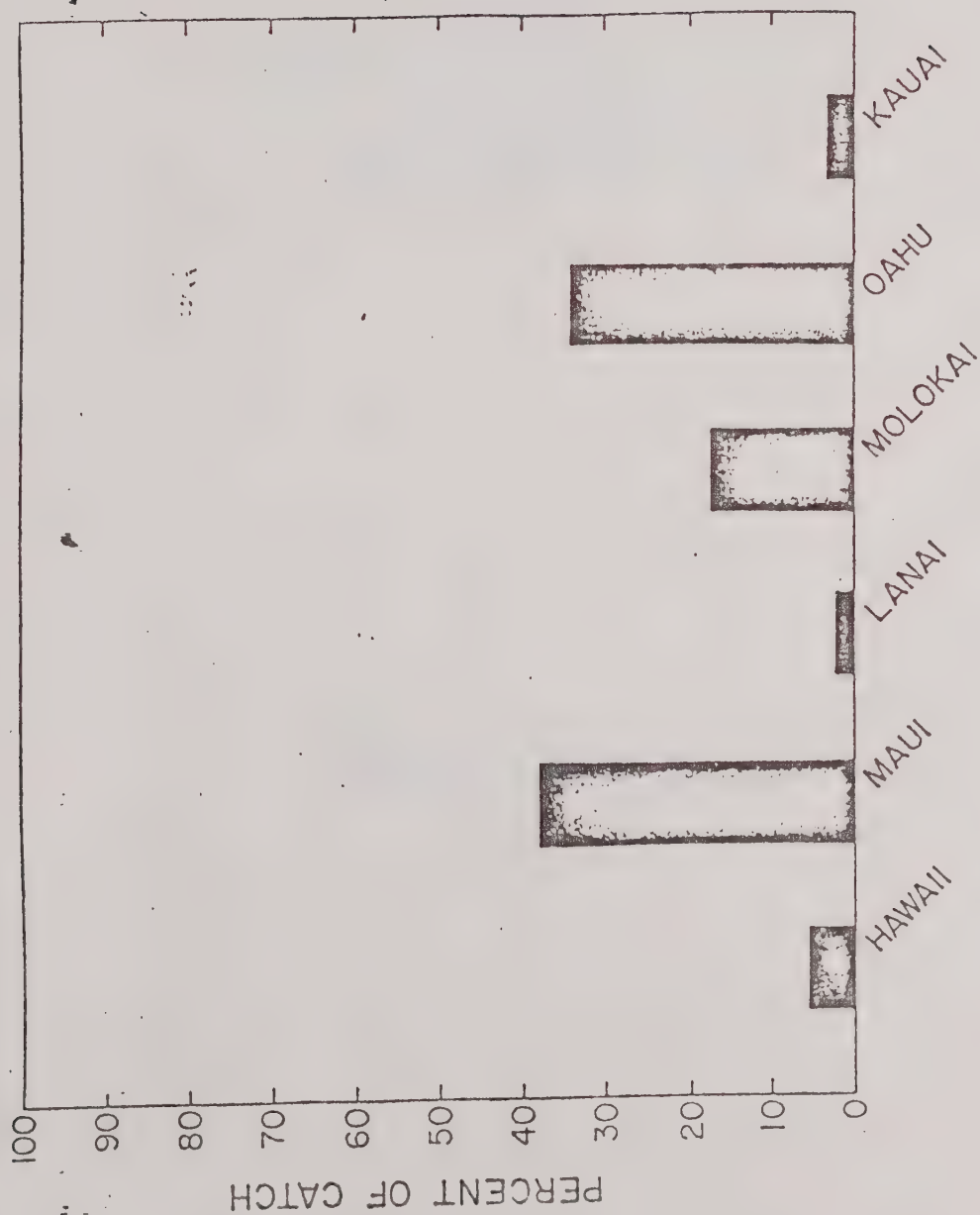


Figure 13. Percent turtle reported as being commercially captured for each of the main islands, 1948-1973.

ALTERNATIVE FISHERY
STATISTICAL INFORMATION SYSTEMS
FOR
CENTRAL AND WESTERN PACIFIC REGIONS
WITHIN MANAGEMENT PURVIEW OF THE
UNITED STATES
WESTERN PACIFIC REGIONAL
FISHERY MANAGEMENT COUNCIL

FEB 14 1980

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Contractor

NOAA Contract No. 03-7-208-35257

April, 1979

PREFACE

This report was prepared by Living Marine Resources, Inc. under NOAA contract number 03-7-208-35257. The contract objective was to develop fishery statistical information systems for collection of catch and effort statistics from commercial and recreational fisheries in Hawaii, American Samoa, Guam, and the Northern Marianas to meet the needs of the Western Pacific Regional Fishery Management Council. The statements, findings, conclusions, and recommendations included herein are those of the contractor and do not necessarily reflect the views of the National Marine Fisheries Service.

Richard S. Shomura
Director, Honolulu Laboratory
September 1979

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1. INTRODUCTION

This document represents the final report by Living Marine Resources, Inc. on work done in fulfillment of contract number 03-7-208-35257, entitled "Fishery Statistical and Information System." The objectives of contract work and this report, as stated in RFP NASO 7-35257, are

"...to develop fishery statistical information systems for collection of catch and effort statistics from both commercial and recreational fisheries in Hawaii, American Samoa, Guam, and the Northern Marianas to meet the management needs of the Western Pacific Regional Fisheries Management Council."

More specifically, the contract objectives and scope of work are to:

"1. Specify statistical and information needs of WPRFMC, Department of Commerce, State of Hawaii, American Samoa, Guam, and Northern Mariana Islands.

"2. Evaluate present marine fishery statistical and information systems in Hawaii, Guam, American Samoa, and Northern Mariana Islands and determine shortcomings with respect to the needs spelled out in Objective 1.

"3. Develop alternative systems, either modifications of existing systems or totally new systems, that will satisfy the needs specified in Objective 1 and be as compatible as possible with existing state and territorial systems including the regional data management system.

"4. Develop cost-benefit analysis of alternative systems.

"5. Evaluate and rank alternative systems according to cost-benefit analysis, compatibility with existing systems, and practicality of implementation.

"6. For the top two or three systems, develop implementation procedures and timetables."

As stated above and elsewhere in the RFP, "The...study relates to the collection of biological data." While important, economic and sociological data requirements are outside the terms of reference of this study and are consequently not addressed in this report.

The report that follows is organized in five sections. This introduction comprises Section 1. Section 2 summarizes the principal points and conclusions discussed in detail in Appendices 6.1 and 6.2 (described below): the major users of fishery information in the central and western Pacific within the purview of the Western Pacific Regional Fishery Management Council are identified and their institutional objectives and jurisdictions defined; all of the major fisheries, and those of priority interest to the Council are delineated; the catch and effort indices - the actual data to be collected - deemed required by the Council as well as the National Marine Fisheries Service (NMFS) and state, territorial and commonwealth fishery agencies are listed, and; the specific catch and effort information needs of the Council are described, along with the degree to which current data collections activities satisfy Council requirements.

Section 3 defines the important features of a "management information system" (MIS), describes the results of the detailed agency-by-agency examination of data collection and processing alternatives contained in Appendix 6.3 (described below), and presents three MIS' recommended as most practical and feasible for the region.

In Section 4, possible procedures for implementing alternative MIS' recommended in Section 3 are described.

Sections 1-4 assemble the principal study observations, issues, conclusions and results, thus comprising the main body of the report. Section 5 summarizes the results of the study. Section 6 assembles as appendices considerable detailed information and analyses necessary as a preliminary to the formulation of study conclusions. Appendix 6.1 provides a detailed examination of the catch and effort information needs of the Council and each fishery agency under the purview of the Council. Appendix 6.2 compares fishery information needs, as defined in 6.1, to data presently produced by existing fishery data collection systems on an agency-by-agency basis in order to identify areas where data availability falls short of requirements. Appendix 6.3 presents data collection and processing alternatives for each fishery agency, and compares and ranks these alternatives as to their cost, practicality and feasibility. Appendix 6.4 gathers the data collection forms presently utilized by each fishery agency. Appendix 6.5 presents a pilot logbook proposal for region recreational fisheries formulated by National Marine Fisheries Service and the Hawaii Division of Fish and Game.

2. FISHERY INFORMATION REQUIREMENTS OF THE WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL - THE ADEQUACY OF CURRENT COLLECTION ACTIVITIES

A poll of the various users of fishery information in American Samoa, Guam, Hawaii and the Northern Mariana Islands as to their institutional objectives and biological data needs to fulfill those objectives initiated contract work. This field work identified the American Samoa Office of Marine Resources, the Guam Aquatic and Wildlife Resources Division, the Hawaii Division of Fish and Game, the Northern Marianas Fishing Authority, the National Marine Fisheries Service - Honolulu Laboratory, and the Western Pacific Regional Fishery Management Council as those agencies primarily responsible for the collection or utilization of basic fishery data in the region. These six agencies and their institutional objectives - to which fishery data are an input - and areas of jurisdiction are identified and summarized in Table 1 as a first step in the determination of fishery information needs in the central and western Pacific.

Another objective of the initial project field work was to identify all the domestic and foreign fisheries in the region, as well as their magnitude and characteristics, for which fishery data are required, and more specifically, those fisheries (focus fisheries) of management interest to the Council. This provides an important indicator of the magnitude of the data collection and processing task. Table 2 summarizes this information, which is discussed in detail by area in Appendix 6.1, listing all the fisheries of any significance in each area and indicating those of Council concern.

Discussions with agency personnel, fishermen and scientists, and analysis of agency objectives and information requirements yielded the list of catch and effort indices shown in Table 3. These indices encompass all the data to be collected in each area. The same table formats including all indices are utilized in the detailed agency-by-agency and fishery-by-fishery analyses of data requirements and the adequacy of current data collection activities contained in Appendices 6.1 and 6.2. Of course, the type and range of indices to be collected vary by fishery and agency.

Tables 4 and 5, using the above-mentioned format, list the fisheries in the region of primary Council concern and details of catch and effort data requirements of the Council in each fishery. Table entries indicate the specific data items and the required periodicity of collection need by the Council in order to fulfill its mandate of preparing and updating management plans for fishery resources - with the exception of tuna resources - in the fishery conservation zone seaward of the State of Hawaii, the Commonwealth of the Northern Marianas and the Territories of Guam and American Samoa. These plans are to contain a detailed description of the relevant fishery, an assessment of the present and probable future condition of the fishery, its maximum sustainable and optimum

TABLE 1. Major Fishery Data User Groups in the Central and Western Pacific and Their Institutional Mandates and Jurisdiction.

● USER GROUP

American Samoa Office of Marine Resources

OBJECTIVES

Conservation and management of Territorial Marine Resources by providing accurate descriptive data on present fishing activities, developing and implementing productive research programs, and by encouraging and assisting in the development of Samoan fisheries.

JURISDICTION

Marine waters surrounding each island seaward out to three miles from shore.

● USER GROUP

Guam Aquatic and Wildlife Resources Division

OBJECTIVES

Make estimates on total fish catch, determine results of different fishing methods, areas fished and the amounts of each species taken. Determine fish population trends in order to formulate effective management programs.

JURISDICTION

For marine waters, that ocean area surrounding the island seaward out to three miles from shore.

Table 1 (Cont.)

● USER GROUP

Hawaii Division of Fish and Game

OBJECTIVES

Development and management of State renewable aquatic resources for wisest and optimal utilization.

JURISDICTION

Presently not clearly defined; traditional three-mile limit around individual Islands recognized by Federal Government; the State claims extended jurisdiction based on archipelago theory.

● USER GROUP

Northern Marianas Fishing Authority

OBJECTIVES

Monitor fishing activities for regulatory, conservation and development planning purposes.

JURISDICTION

Marine waters surrounding each island seaward out to three miles from shore.

● USER GROUP

National Marine Fisheries Service, Honolulu Laboratory

OBJECTIVES

Develop and implement research programs that produce data and knowledge necessary for the protection, wise use and management of United States living marine resources. Assist in the development and maintenance of commercial and recreational marine fisheries, as well as the aquaculture industry. Conserve and manage fish resources in the Fishery Conservation Zone (FCZ) - defined as that area seaward of the boundaries of state/territorial jurisdiction out to 200 nautical miles.

Table 1 (Cont.)

JURISDICTION

For research purposes, all marine waters, including estuaries, from shore out to the limits of the FCZ; with respect to conservation and management responsibilities, area of jurisdiction corresponds with that of the WPRFMC (see below).

• USER GROUP

Western Pacific Regional Fishery Management Council

OBJECTIVES

Prepare fishery management plans, and from time to time, such amendments to plans as are necessary; review on a continuing basis and revise as appropriate assessments of present and probable future condition of relevant fisheries, their maximum sustainable yields and harvest available to foreign fishermen.

JURISDICTION

Those fishery resources (including precious coral) in the FCZ around Hawaii, American Samoa and Guam. Also, those fishery resources which are primarily exploited in the FCZ (in cases when exploitive activities take place in both state/territorial and FCZ waters). Inshore resources may also fall under WPRFMC purview in special cases, such as when state or territorial authorities lack the capability to manage such resources deemed requiring management.

Table 2. Agency cross-interests in all regional fisheries. Fisheries for which data is needed by the WPRFMC are focus fisheries.

Fishery	Agency					
	Western Pacific Regional Fishery Management Council	National Marine Fisheries Service	American Samoa Office of Marine Resources	Guam Aquatic and Wildlife Resources Div.	Hawaii Fish and Game	Northern Marianas Fishing Authority
American Samoa						
Diving			x			
Handline						
Commercial			x			
Subsistence			x			
Shoreline						
Handpicking			x			
Hook and line			x			
Stationary nets, weirs			x			
Throw nets			x			
Traps			x			
Troll						
Commercial/charter	x $\frac{1}{1}$		x			
Small boat	x $\frac{1}{1}$		x			
Guam						
Inshore						
Handpicking and spear (diving)				x		
Hook and line				x		
Net				x		
Offshore						
Handline				x		
Spear (diving)				x		
Troll	x $\frac{1}{1}$			x		
Ponds, Weirs				x		
Hawaii						
Diving						
Aquarium						x
Spear, gathering						x
Handline						
Akule/opelu						x
Deepsea (bottomfish)		x				x
Inshore (bottomfish)						x
Tuna	x $\frac{1}{1}$	x $\frac{3}{3}$				x

Table 2 (Cont.)

Fishery	Agency					
	Western Pacific Regional Fishery Management Council	National Marine Fisheries Service	American Samoa Office of Marine Resources	Guam Aquatic and Wildlife Resources Div.	Hawaii Fish and Game	Northern Marianas Fishing Authority
Hawaii (Cont.)						
Longline ("ahi")	x ^{1/}	x ^{3/}			x	
Net						
Akule					x	
Bait					x	
Gill net					x	
Tangle (crab)					x	
Trawl					x	
Pole and line ("aku")	x ^{1/}	x ^{3/}			x	
Pond					x	
Precious coral	x				x	
Shoreline						
Handpicking					x	
Pole and line					x	
Throw nets					x	
Trap						
Bottomfish	x ^{2/}				x	
Crab					x	
Lobster	x				x	
Shrimp					x	
Troll						
Commercial/charter	x ^{1/}	x ^{3/}			x	
Small boat	x ^{1/}	x ^{3/}			x	
Northern Marianas						
Commercial line					x	
Small boat						
Inshore					x	
Offshore	x ^{1/}				x	
Traps, weirs					x	
Internat'l and Foreign Fisheries						
Domestic tuna						
Pole and line ("aku")		x				
Purse seine		x				
Troll		x				

Table 2 (Cont.)

Fishery	Agency
Int'l and Foreign Fisheries (Cont.)	
Foreign	
Bottomfish	
Line	x ₂ /
Trawl	x ₂ /
Precious coral	x ₁ /
Tuna longline	x ₃ /
Tuna pole and line	x ₃ /

1/ Primarily billfish, dolphin (mahimahi), shark and wahoo.

2/ Primarily NW Hawaiian bottomfish.

3/ Primarily tuna.

TABLE 3. Useful catch and effort - identified by agency personnel in the Western Pacific Regional Fisheries Management Council area.

Effort Indices	
Effort description ^{1/}	
Number of fishermen (anglers)	
Number of vessel-trips	
Number of angler-trips	
Days/hours absent	
Days/hours searching	
Days/hours fishing	
Statistical area	
Area fished (dragged, pond)	
Depth gear set	
Number of hooks/traps/lines nets	
Bait type	
Bait quantity used	
Number of gear sets	
Number of successful sets	
Catch Indices	
Number of schools sighted	
Number of schools fished	
Number of fish caught/landed	
Weight of fish caught/landed	
Statistical area of catch	
Date/time of catch	
Depth of catch	
Species composition	
Size composition (by species)	
Sex composition (by species)	

^{1/} "Effort description" encompasses such data as vessel/fishermen identification, vessel and fishermen numbers, vessel characteristics (owner's and captain's name, radio call sign, vessel length, beam, tonnage, engine size, fuel/bait/fish hold capacity, gear type and description, crew size, and port), other gear characteristics, port and landing/launching site characteristics, and possibly fishermen profile information.

TABLE 4. Fishing effort data needs, Western Pacific Regional Fishery Management Council. Entries reflect desired data collection periodicity.^{1/} Underlined entries are essential data.

Fishery	Effort Data										
	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets
											Bait type
											Bait quantity used
											No. gear sets
											No. successful sets
Billfish ^{2/}											
	Dom. commercial/charter troll	7					<u>4</u>	<u>4</u>			<u>4</u>
	Domestic small boat troll	7		<u>4</u>			<u>4</u>	<u>4</u>			<u>4</u>
	Domestic tuna handline	7	<u>4</u>				<u>4</u>	<u>4</u>			<u>4</u>
	Domestic tuna pole and line	7				4	<u>4</u>	<u>4</u>			<u>4</u>
	Tuna longline ^{3/}	7					<u>4</u>	<u>4</u>			<u>4</u>
Bottomfish ^{4/}											
	Domestic NW Hawaiian handline	7					<u>4</u>	<u>4</u>			<u>4</u>
	Domestic NW Hawaiian trap	7					<u>4</u>	<u>4</u>			<u>4</u>
	Foreign line	7					<u>4</u>	<u>4</u>			<u>4</u>
	Foreign trawl	7					<u>4</u>	<u>4</u>	4		
NW Hawaiian lobster ^{5/}		7					<u>4</u>	<u>4</u>			4
Precious coral											
	Domestic Hawaiian	7	<u>4</u>				<u>4</u>	<u>4</u>			
	Foreign	7					<u>4</u>	<u>4</u>	4		

- ^{1/} Symbols. Periodicity: 1=by trip 5=quarterly
2=daily 6=yearly
3=weekly 7=by periodic survey
4=monthly
- ^{2/} Includes species often taken with billfish (e.g. dolphin, pelagic shark, wahoo).
- ^{3/} Domestic and foreign fisheries.
- ^{4/} Includes alphonsins, armorheads.
- ^{5/} Only the NW Hawaiian fishery is currently of interest to the WPRFMC.

TABLE 5. Fishery catch data needs, Western Pacific Regional Fishery Management Council. Entries reflect desired data collection periodicity.^{1/} Underlined entries are essential data.

Fishery	Catch Data								
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition	Size composition (by species)
Billfish ^{2/}									
Dom. commercial/charter troll			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	4
Domestic tuna small boat troll			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	
Domestic tuna handline			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	4
Domestic tuna pole and line				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Tuna longline <u>3/</u>			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	4
Bottomfish ^{4/}									
Domestic NW Hawaiian handline				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Domestic NW Hawaiian trap				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Foreign line				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Foreign trawl				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Domestic NW Hawaiian lobster ^{5/}			<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	<u>4</u>
Precious coral ^{6/}				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	

^{1/}, ^{2/}, ^{3/}, ^{4/}, ^{5/} See footnotes, Table 4.

^{6/} Domestic and foreign fisheries.

yield, the capacity of American fishermen to exploit the resource, and the amount, if any, available for foreign exploitation. Additionally, conservation and management measures applicable to both foreign and domestic fishermen are to be formulated.

Council information requirements shown in Tables 4 and 5 are the product of the exhaustive analysis of individual agency data needs referenced in Appendix 6.1. This is because nearly all of the required effort and catch/landing data describing domestic activities will be supplied by State/Commonwealth/Territorial data collection systems. In isolated cases, Council needs for more detailed data may require collection activities under Council auspices in certain domestic fisheries. Arrangements for collection of required data describing targeted foreign fishing activities will necessarily be the responsibility of NMFS. Foreign and domestic fisheries exploiting billfish, precious coral, bottomfish (including alphonsons and armorheads) and NW Hawaiian lobster are targeted by the Council. With the exception of effort descriptive data, a monthly compilation of specified data items is thought adequate. Data needs in the tuna handline, tuna longline and troll fisheries relate only to billfish, not tuna.

Tables 6 and 7 compare present data collection activities of State/Territory/Commonwealth fishery agencies in the region with information requirements as formulated for the Council above. These tables represent a synthesis of the detailed agency-by-agency examination of current data collection activities of local agencies and the degree to which they fulfill local and Council information requirements contained in Appendix 6.2. In Tables 7 and 8, current local agency data collection activities are described with respect to the degree to which they satisfy Council, not local agency needs.

Where current data collection activities do not satisfy Council needs, non-satisfaction is of three types. First, some data items deemed essential by the Council are judged either only helpful (not essential) or not needed at all by the appropriate collecting agency. Second, some data items are seen as requiring more frequent collection by the Council than by the collecting agency. Third, even when priority and collection periodicity match, for some data items current collection activities are inadequate to meet needs.

In certain instances of non-satisfaction of Council data requirements, especially of type one or two (above), the Council may find it necessary to institute either one-time (e.g. a fishery profile survey) or continuing data collection programs to gather the required essential information.

Table 6. Degree to which current agency data collection activities satisfy Western Pacific Regional Fishery Management Council effort data needs (Table 12). Entries for essential needs underlined.1/

Fishery	Effort Data										
	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets
Billfish ^{2/}											
Domestic comm./charter troll,											
Amer. Samoa OMR <u>3/</u>	S						<u>S</u>	<u>N</u>			<u>N</u>
Hawaii DFG	S						<u>S</u>	<u>N</u>			<u>N</u>
Domestic small boat troll,											
Amer. Samoa OMR	S			<u>N</u>		N	<u>N</u>				N
Guam AWR	S			<u>N</u>		2	<u>N</u>				2
Hawaii DFG	S			<u>N</u>		S	<u>N</u>				N
N. Marianas offshore FA ^{4/}	S			<u>N</u>		N	<u>N</u>				N
Domestic tuna handline,											
Hawaii DFG	S		<u>5</u>			5	<u>N</u>				N
Domestic tuna pole and line,											
Hawaii DFG	4					N	<u>4</u>	<u>N</u>			<u>4</u>
Tuna longline,											
Domestic, Hawaii DFG	S						<u>S</u>	<u>N</u>			<u>S</u>
Foreign, NMFS	4						<u>4</u>	<u>4</u>			<u>4</u>
Bottomfish											
Domestic fisheries ^{5/}											
NW Hawaiian handline, DFG ^{6/}	S						<u>S</u>	<u>S</u>			<u>S</u>
NW Hawaiian trap DFG ^{6/}	S						<u>S</u>	<u>S</u>			<u>S</u>
Foreign fisheries											
Line, NMFS	N						<u>N</u>	<u>N</u>			<u>N</u>
Trawl, NMFS	N						<u>N</u>	<u>N</u>	N		
NW Hawaiian lobster ^{7/}											
Hawaii DFG ^{6/}	S						<u>S</u>	<u>S</u>			S
Precious coral											
Domestic Hawaii DFG	5		<u>5</u>			5	<u>5</u>				
Foreign, NMFS	N					<u>N</u>	<u>N</u>	N			

Table 6 (Cont.)

-
- / Entry Symbols: Degree to which needs are satisfied.
1= 0 - 25 percent N= Data not collected
2= 26- 50 S= Some data collected.
3= 51- 75 Degree to which needs
4= 76- 89 satisfied not known.
5= 90-100 U= Data collection unknown.
- 2/ Billfish includes dolphin (mahi mahi), shark, wahoo.
- 3/ Agency abbreviations.
- 4/ N. Marianas small boat troll is part of "small scale offshore" fishery.
- 5/ Only those domestic FCZ fisheries for this species group in areas where there is a foreign fishery for this species group are of management interest to the WPRFMC.
- 6/ Includes NMFS data collection activities for Hawaii DFG.
- 7/ Only the NW Hawaiian fishery is currently of management interest to the WPRFMC.

Table 7. Degree to which current agency data collection activities satisfy Western Pacific Regional Fishery Management Council catch data needs.^{1/} Entries for essential needs are underlined.

Fishery	Catch Data							
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition
								Size composition (by species)
								Sex composition (by species)
Billfish ^{2/}								
Dom. comm./charter troll,								
Amer. Samoa OMR <u>3/</u>			<u>2</u>		<u>N</u>	<u>2</u>		<u>2</u> N
Hawaii DFG			<u>S</u>		<u>S</u>	<u>S</u>		<u>S</u> N
Domestic small boat troll,								
Amer. Samoa OMR			<u>S</u>		<u>S</u>	<u>S</u>		<u>S</u>
Guam AWR			<u>2</u>		<u>2</u>	<u>2</u>		<u>2</u>
Hawaii DFG			<u>S</u>		<u>S</u>	<u>S</u>		<u>S</u>
N. Marianas offshore FA ^{4/}			<u>S</u>		<u>N</u>	<u>S</u>		<u>S</u>
Domestic tuna handline								
Hawaii DFG			<u>S</u>		<u>S</u>	<u>S</u>		<u>S</u> N
Domestic tuna pole and line								
Hawaii DFG				<u>5</u>	<u>4</u>	<u>5</u>		<u>5</u>
Tuna longline								
Domestic, Hawaii DFG			<u>S</u>		<u>5</u>	<u>5</u>		<u>5</u> N
Foreign, NMFS			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u> N
Bottomfish								
Domestic fisheries ^{5/}								
NW Hawaiian handline, DFG <u>6/</u>				<u>5</u>	<u>5</u>	<u>5</u>		<u>5</u>
NW Hawaiian trap, DFG <u>6/</u>				<u>5</u>	<u>5</u>	<u>5</u>		<u>5</u>
Foreign								
Line, NMFS				<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>
Trawl, NMFS				<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>
NW Hawaiian lobster trap ^{7/}								
Hawaii DFG <u>6/</u>			<u>S</u>	<u>5</u>	<u>5</u>	<u>5</u>		<u>5</u> <u>S</u>
Precious coral								
Domestic, Hawaii DFG				<u>5</u>	<u>5</u>	<u>5</u>		<u>5</u>
Foreign, NMFS				<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>

^{1/}, ^{2/}, ^{3/}, ^{4/}, ^{5/}, ^{6/}, ^{7/} See footnotes, Table 6.

3. ALTERNATIVE MANAGEMENT INFORMATION SYSTEMS

3.1 INTRODUCTION

The objective of this section is to develop alternative "management information systems" (MIS) to gather, store and make available in a convenient form catch and effort data necessary for preparation of management plans for the Western Pacific Regional Fishery Management Council.

For this report, an MIS is considered to be composed of three parts. The first, data collection and reporting, consists of techniques, equipment and personnel necessary to gather needed data in the field. The second, data reduction, consists of techniques, equipment and personnel necessary to convert basic collected data into usable form. The third, storage and retrieval, consists of equipment and personnel necessary to store and edit master Council data files and to retrieve data subsets from these files for analysis, principally by the Council's management plan development teams.

In contrast to the discussion of all agency data needs in Sections 2 and 3, this and remaining section deal primarily with those fisheries and catch/effort data items identified as essential to satisfying the Council's mandate. Alternate management information systems are developed to collect, process, store and retrieve data.

Collection of fishery data not needed by the Council is not formally developed. However, the systems proposed are compatible with existing agency systems.

To facilitate the discussion of alternate MIS', the following are assumed:

1. Alternative MIS' are computer-based.
2. Data collection produces raw fishery catch/effort data recorded on collection forms designed for direct key punching without transcription onto coding forms.
3. Data reduction produces verified and validated data in standard format, in electronically readable form ready to merge with existing master files.
4. Storage and retrieval alternatives take reduced data, if necessary convert formats to Council standards, merge new data with existing files and produces subfiles for use by council analysis.

3.2 DATA COLLECTION

Data collection encompasses techniques, personnel and equipment necessary to gather catch/effort data from original sources. Typically, data sources include individual fishermen, organized fishermen's cooperatives, individual buyers, and wholesale and retail market participants. Techniques fall into three general types: vessel logbooks or periodic reporting by fishermen; periodic surveys or interviews of fishermen or markets; and fish tickets completed by first buyer to record the flow of fish through commercial channels.

The logbook approach provides detailed catch and effort information by area of capture. The logbooks are completed by the vessel captain. Log completion and submission may be mandatory (usually tied to a fisherman licensing system) or voluntary. A voluntary logbook system usually produces less data than does a mandatory system. However, the voluntary method produces better quality information. When only a small number of fishermen or vessels are involved, logs can be placed with each operating gear. However, when there are a large number of operators, a sample of the total will suffice. Logbooks are an effective technique to gather detailed information on fishing operations in fisheries where extended trips are usual.

Survey techniques utilize trained personnel to circulate among fishermen, gathering the required information through interviews of all or a sample of all operators. This approach is particularly effective, and not faced with prohibitive costs, when fishermen are accessible at a central gathering point - a principal harbor or market. Survey costs mount sharply as the dispersion of interviewees increases.

A fish ticket system requires that at least a major portion of the catches on which data are to be gathered enter commercial channels. The tickets are completed - and data generated - by the buyer when the fisherman sells his catch. All fish buyers - wholesale and retail dealers, processors and in some cases, brokers - are usually required to complete a ticket for each purchase. A copy of each ticket is submitted by the buyer to the collecting agency; data on these tickets become the basic data for the system. The fish ticket approach lends itself to the collection of data on the quantity landed, by species, area and gear; value by species is also obtained.

Details of the three techniques, as well as necessary personnel and equipment, for each western Pacific collecting agency are discussed in Appendix 6.3. Included in the appendix discussion is an agency-by-agency ranking of the alternatives. Table 8 summarizes the results of this ranking.

TABLE 8. Summary results of ranking individual agency data collection and reduction alternatives aimed at WPRFMC needed fishery data.^{1/}

Agency/fishery	Data Collection Alternatives				Data Reduction Alternatives	
	Fish Ticket	Log	Survey	Log Survey	Local	Central
American Samoa troll ^{2/}	-	1	2	-	2	1
Guam troll	-	3	1	2	1	2
Hawaii					2	1
Longline	1 ^{4/}	1	2	-		
NW bottomfish/lobster ^{3/}	1 ^{4/}	1	2	-		
Pole and line	1 ^{4/}	1	-	-		
Precious coral	-	1	-	-		
Troll ^{2/}	1 ^{4/}	1	-	-		
Tuna handline	1 ^{4/}	2	1	-		
Northern Marianas troll	-	1	2	-	2	1
NMFS (foreign fish)					1	2
Tuna longline	-	1	-	-		
Bottomfish line/trawl	-	1	-	-		
Coral trawl	-	1	-	-		

^{1/} Symbols: 1=first rank; 2=second rank; 3=third rank;
 -=option not developed.

^{2/} Combines commercial/charter and small boat troll fisheries.

^{3/} Combines line and trawl bottomfish and lobster trap fisheries.

^{4/} The existing Hawaiian fish ticket system should be continued to collect data from those fisheries where the catch is sold.

3.3 DATA REDUCTION

Once collected, basic fishery catch/effort data needed by the Council must be translated (or reduced) from field collection forms to a format for storage and retrieval in the central computer system.

Data reduction encompasses data entry, verification and validation, leading to periodic merging of new data files with central master files. Data is entered either onto paper cards (punched) or written onto a magnetic medium (e.g. tape or disk) via a cathode ray tube (CRT) or hardcopy (e.g. teletype) keyboard terminal.

Following entry, the new data file must be verified, and checked against the original data forms. On a card-based system, the new card file is printed, then data items on each card image checked by hand. New cards are punched to replace ones containing errors. Verification on tape or disk-based system is considerably easier. Individual records (e.g. lines) are listed one at a time and checked directly by the terminal operator who makes necessary character or line changes at the terminal.

Following entry and verification, individual data items are validated or checked for consistency. This requires analysis to assure that values of data items are in ranges known to be appropriate for the particular item.^{1/} Data can be validated using a computer program designed for the purpose or by graphing. During validation, questionable data items are flagged, then checked against original collection forms.

When a data file has been entered, verified and validated, it is transmitted to the central site to be merged with the appropriate Council master file. The format of data in any file created by data reduction need not be the same for all agencies submitting data to the system. As long as the data is present, in a usable format (e.g., card, tape of readable density, characters in readable code, etc.), and central site personnel know the format, data records can be easily translated into the Council's format at the central storage and retrieval system site.

There are three alternatives for reducing basic fishery data for use in the system - reduction by the collecting agency, central reduction at the same site at which Council master files are maintained, or mixed local and central reduction.

^{1/} e.g., for most marine fish species, the relation between length and weight is characteristic and known. In this case, length-weight data pairs in the new file could be checked to assure that weights fall within reasonable confidence intervals for given lengths, etc.

Local reduction requires that minimum data processing capabilities (personnel and machinery) be available to each collecting agency. Additionally, the agency must be able to reduce and transmit completed files to the Council on a timely basis. With local reduction, only minimal processing of received files (e.g., translation to Council formats) is necessary, thus reducing needed central site requirements. However, complete periodic updating of the master files proceeds at the pace of the slowest local agency. Additionally, the quality of data entry, its verification and validation is beyond the Council control.

Central reduction places no processing capability requirements on collecting agencies who submit collection forms or transcribed original data to the central site. Central reduction requires maximum central site processing capability. However, the entire process is under direct Council control, assuring consistent verification and validation quality. Assuming timely submission of original data, periodic control file updating is dependent only on the pace of the central organization.

Mixed site reduction allows local reduction by those agencies where this can be done while enabling central reduction of data from those agencies not having appropriate capability. Mixed site reduction, as opposed to central, probably would result in less than proportionate reduction in central site processing capabilities, since capacity sufficient to process part of the total incoming data would probably be almost, if not entirely, sufficient for doing the whole job. Reduction quality control and central file update timeliness would be more than that for local reduction and less than with central reduction.

Features of reduction facilities available to area agencies, as well as the feasibility of local reduction of agency-collected data is discussed in Appendix 6.3. Benefits and costs of local versus central reduction are assessed, resulting in a ranking of options for each agency (ranking summarized in Table 8).

3.4 DATA STORAGE AND RETRIEVAL

Following collection and reduction, data required by the Council must be stored in some central computer facility. The storage system should feature easy access for file entry via cards or tape (of different densities), efficient editing and subfile creation, permanent off-line disk or tape file storage, temporary on-line file storage, implement standard FORTRAN, and most importantly, allow jobs (editing, file creation, programming, program analysis of subfiles) to be submitted remotely, preferably by terminals located at a site convenient to data users.

Ideally, system access terminals should be housed in a facility sufficiently large and central to enable data processing personnel and data users (principally plan development teams) easy access to data files. Data processing staff members need the capability to reduce raw data, periodically update master files with newly reduced data and in general to maintain central files. Data file users need the capability to analyze master files subsets - in the case of catch/effort data, generally by population dynamic analyses. Additionally, user/analysts will probably require periodic scientific programming, as well as data processing support.

Alternative sources of computer capability (computer, disk/tape storage, data transmission lines software, etc.) for the central file system include commercial time share service vendors and the NMFS-contracted time share service (INFONET). According to the Southwest Fisheries Center Data Manager, all Federal Government computer facilities in Honolulu are nearly fully utilized and not available. As outlined in Appendix 6.3, both University of Hawaii and Hawaii State systems are also fully utilized. The expected level of usage does not warrant Council purchase of a computer system and hiring of attendant operating personnel.

The expected relatively small data files and light usage suggest that commercial systems are probably not feasible, as customer service may not be adequate for a small user. However, Council computer needs could be added to those of NMFS-Honolulu, already making extensive use of INFONET. Thus, big-user service would be available to the Council. Additionally, Council plan development team analytic efficiency would be enhanced by use of INFONET since most teams will include at least one NMFS-Honolulu Laboratory scientist likely to be familiar with INFONET use. Council use of augmented NMFS/INFONET service is recommended.

Master file updating involves converting reduced data files to standard format where necessary, then merging new files with existing masters. At the expected level of activity and assuming monthly updating, this should require the services of no more than .1 man-year's programmer/facility manager time and .25 man-year's technician time. Access to a card/tape reader and .25 machine-year's data editing terminal are also needed.

Data file maintenance should likewise require .1 man-year's programmer and .25 man-year's technician time and .25 machine-year's editing terminal time.

Data processing capabilities necessary for users to assess and analyze data subsets depends on expected volume of use. As a rough approximation, .5 man-year's technician time and .5 machine-year's data editing terminal time should be sufficient. Access to a line printer is needed, although results of most analyses can probably

be output directly at the data editing terminal with little or no printing of volumes of information necessitating a line printer. Approximately .5 man-year's programmer time should be sufficient to support analyst activities.

Thus, as a first approximation, .7 man-year's programmer and 1.0 man-year's data processing technician time is needed at the central site. Additional technician time will also be necessary to reduce data where local reduction is not practical. Remaining programmer time (.3 man-years) could be used profitably for general supervisory work. Required technical labor could be borrowed from cooperating agencies such as NMFS. However, the required level of labor, plus the need for continuity, suggests that the best approach would be to hire these persons as members of the Executive Director's staff.

Minimum equipment necessary to maintain Council data files and to facilitate subfile analysis includes two data entry/editing terminals to be connected remotely via telephone lines to the computer system. Such terminals can be either CRT-based or printing. A useful combination would be one of each type. Equipment can be purchased, leased or borrowed from friendly agencies (NMFS, University of Hawaii), or commercial time share computer vendors if their system is used. Should listing large quantities of data or output become necessary, a small 132 column line printer may be desired. Access to keypunch machines, a card reader and tape readers will be needed for entry of agency-reduced data. This should be available through cooperating agencies (NMFS, Coast Guard).

Council data processing personnel and equipment should be housed in a central location where space is available for the plan development teams, the principal data base users. Alternative locations include the Council staff's Honolulu headquarters and the NMFS Honolulu Laboratory. The NMFS location presumably would be provided as part of NMFS support of Council activities. The cost of space at the Council headquarters would be at the commercial rate for this space. Locating at NMFS would carry the additional benefit of proximity to NMFS ADP personnel, as well as substantial scientific expertise. If space is available, NMFS Laboratory housing of Council ADP personnel and equipment is preferable to use of Council headquarter space.

3.5 ALTERNATIVE SYSTEMS

A complete alternative management information system consists of a particular data collection technique for each of the 12 fisheries listed in Table 8, and either local or central data reduction for each of the 4 agencies. Central storage and retrieval on the NMFS-used computer in Honolulu and staff location at the NMFS-Honolulu Laboratory are assumed. Thus, there are

3,072 theoretically feasible alternative MIS'.^{1/}

The most obvious MIS is that composed of first rank alternatives for each agency-system part component of the system. For illustrative purposes, second and third alternatives can be identified.

The second alternative incorporates local rather than central reduction of American Samoa and Northern Marianas data. The quantitative cost of both reduction alternatives in these areas are identical; the ranking of central over local reduction is based on qualitative considerations (Table 9 and Appendices 6.3.3.1 and 6.3.3.4).

The third alternative is that composed of first rank data reduction techniques and second rank agency collection techniques. This alternative is motivated by the fact that quantitative costs of first versus second rank collection techniques are similar in all cases (Table 9).

^{1/} (2 Samoa collection options) x (2 Samoa reduction options) x
(3 Guam collection options) x ... = 2x2x3x... = 3x2 = 3,072.

TABLE 9. Annual personnel and equipment requirements (in man-years and machine-years) by type for all agencies, all alternatives of all system parts of the Council Information Management System. Summary requirements for three suggested alternative complete systems are listed.

Agency Activity	Alternative Rank	Data Collection		Data reduction		Data storage and retrieval	
		Personnel ^{1/}	Personnel ^{2/}	Personnel ^{2/}	Equip. ^{3/}	Personnel ^{2/}	Equip. ^{3/}
AMERICAN SAMOA TROLL							
Data collection	1	.15					
Log	2	.25					
Survey	2			.10	.10		
Local data reduction							
GUAM TROLL							
Data collection	1	.30					
Survey	3	.60					
Vol. log	2	.80					
Vol. log/survey							
Local data reduction	1			.00	.00		
HAWAII							
Data collection							
Longline	1	.20					
Log	2	.35					
Survey							
NW bottomfish, lobster							
Log	1	.10					
Survey	2	.20					
Pole and line							
Log 4/	1	-					
Precious coral	1	-					
Log 4/							
Troll	1	- 5/					
Log							
Tuna handline							
Log	2	.50					
Survey	1	.40					
Local data reduction	2			1.00	1.00		

-25-

TABLE 9 (Cont.)

Agency Activity	Alternative Rank	Data Collection Personnel ^{1/}	Data reduction		Data storage and retrieval	
			Personnel ^{2/}	Equip. ^{3/}	Personnel ^{2/}	Equip. ^{3/}
NORTHERN MARIANAS TROLL						
Data collection	1	.50				
Log	2	.80				
Survey	2		.25	.25		
Local data reduction						
NMF ^{5/} S HONOLULU						
Data collection	1					
Log	1	.00	.00	.00		
Local data reduction						
COUNCIL						
Central data reduction						
American Samoa	1		.10	.10		
Guam	2		.50	.50		
Hawaii	1		.75	.75		
N. Marianas	1		.25	.25		
NMFS	2		.50	.50		
Storage retrieval					.70	
Programmer					1.00	
Technician						7/
Card reader						2.00
Entry/editing terminal						7/
Keypunch						7/
Printer						
System 1 ^{8/}	1	1.65	1.10	1.10	1.70	2.00
System 2 ^{9/}	2	1.65	1.10	1.10	1.70	2.00
System 3 ^{10/}	3	2.90	1.10	1.10	1.70	2.00

TABLE 9 (Cont.)

Agency Activity	Alternative Rank	Data Collection Personnel ^{1/}	Data		Data storage and retrieval Personnel ^{2/} Equip. ^{3/}
			reduction Personnel ^{2/} Equip. ^{3/}		
<u>Footnotes:</u>					
		1/	Data collection personnel are biologists.		
		2/	Data reduction personnel are data processing technicians.		
		3/	Data reduction equipment: Key punch or computer connected remote terminals.		
		4/	Existing data collection systems; no additional personnel and equipment required.		
		5/	Pilot study personnel requirement 2.15 man years; continuing requirement not known.		
		6/	Foreign tuna longline, bottomfish line and trawl, coral fisheries.		
		7/	Only occasional access to equipment of this type is necessary.		
		8/	System 1 incorporates first rank data collection and reduction techniques for all agencies.		
		9/	System 2 incorporates qualitatively inferior second rank reduction techniques for American Samoa and Northern Marianas.		
		10/	System 3 incorporates second rank data collection techniques, first rank data reduction techniques for all agencies.		

4. IMPLEMENTATION

The objective of this section is to describe procedures for implementing the three alternative, multi-part management information systems developed in Section 3.

The great number of feasible alternatives makes superfluous the drafting of detailed implementation schedules. The following treatment is intended as a broad overview - a guide to drafting schedules for specific alternatives chosen after deliberation by representatives of all area agencies. An example of a more detailed schedule is the "proposal for a Logbook Pilot Study" (Appendix 6.5).

Implementation of the three sample systems is described - via Tables 10 and 11 - by system part - data collection, data reduction and storage and retrieval. Tables 10 and 11 suggest that, except for the Hawaiian troll log system, implementation of data collection parts of the system is possible by the beginning of month 7. Implementation of the Hawaiian troll log system is delayed - by a 6 month-pilot study - until the beginning of month 13.

Regardless of the specific system implemented, data reduction parts should be operational by the beginning of month 4. The single feasible storage and retrieval option considered should similarly be operational by the beginning of month 4.

Regardless of the specific system, the first two implementation activities are central planning, scheduled for two months for the three sample systems, followed by local, agency level planning. It is essential in a complicated multiple-agency cooperative endeavor such as the proposed information system, that comprehensive planning precede implementation activities. Central planning, involving technical representatives from the Council and the four data collecting agencies, should cover all aspects of system implementation, beginning with collection and reduction responsibilities, continuing through periodicity of data transmission to the central facility, and including central facilities and local agency needs for Council processed data.

Planning should also cover specific data items needed for the Council data base, details of preliminary surveys where needed to determine collection procedures, and possibly format standardization.

An option is for the Council's Scientific and Statistical Committee (SSC) to designate a special planning group to report preliminary conclusions for discussion at a regular SSC meeting. A second meeting might be required prior to the commencement of work on local and central portions of the system.

TABLE 10. Implementation schedule. Alternatives 1 and 2, Western Pacific Regional Fisheries Management Council Information Management System.1/

[illegible]

TABLE 10 (Cont.)

Activity	Month												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Data collection													
Hawaii (Cont.)													
Tuna Handline-Survey													
Procure forms													X--X
Hire, train personnel													X--X
Operational													X
Northern Marianas Troll-Log													
Procure forms													X--X
Hire, train personnel													X--X
Introduce													X--X
Operational													X
National Marine Fisheries Service Log ^{3/}													
Data reduction - All agencies													
Hire and train personnel													X--X
Procure equipment													X--X
Operational													X
Storage and Retrieval													
Procure computer service													X
Hire and train personnel													X--X X--X
Procure equipment													X--X
Operational													X

1/ System descriptions: See footnotes 6, 7 in Table 9.

2/ Established Hawaiian pole and line and precious coral fishery logs are deemed satisfactory. Thus, no implementation plan is needed.

3/ Implementation of the suggested log system to collect NMFS-collected foreign tuna longline, bottomfish and coral fishery data requires high level NMFS personnel time, as well as Department of State cooperation; a schedule is impossible to estimate.

TABLE 11. Implementation schedule, alternative 3, Western Pacific Regional Fisheries Management Council Information Management System.1/

[illegible]

TABLE 11 (Cont.)

Activity	Month												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Data collection													
Hawaii (Cont.)													
Tuna Handline-Log													
Procure forms				X--X									
Hire and train personnel				X--X									
Introduce					X-----X								
Operational							X						
Northern Marianas Troll-Survey													
Procure forms				X--X									
Hire and train personnel				X--X									
Operational					X								
National Marine Fish. Serv.-Log ^{2/}													
Data reduction - All agencies													
Hire, train personnel				X--X									
Procure equipment				X--X									
Operational					X								
Storage and retrieval													
Procure computer service				X									
Hire and train personnel			X--X	X--X									
Procure equipment				X--X									
Operational					X								

^{1/} System description: See footnote 8, Table 9.

^{2/} Implementation of the suggested log system collect NMFS-collected foreign fishery data is impossible to estimate.

FORMS

Figures 1, 2 and 3 are one possible set of effort, catch and biological sample data collection forms. These "universal" forms were not designed to satisfy specific data requirements of any particular western Pacific data collection agency, but rather to encompass all requirements of all agencies. The forms are adequate to collect data either as a log or by survey.

The effort form includes all data items necessary to calculate effort indices identified in Section 1 tables. Vessel-trips and angler-trips are not included, as these are results of analysis, not data. Neither number of gear sets nor number of successful sets are included; these are not strictly effort indices but more indices of school density, school size, fishermen skill, gear size, etc. All other desired effort indices identified in Section 1 either are included as to be collected data items, or can be calculated from included items.

All catch indices identified in Section 1 tables either are included on one of the three forms or can be calculated from included items.

Biological data items on the biological data form are restricted to length, weight and sex, those items likely to be gatherable in the field. Additionally, a space is provided to indicate the taking of biological samples (e.g., otolith, stomach, scale) for subsequent laboratory analysis. Such samples can be uniquely identified by some combination of fishermen or vessel number, data and sample number.

Data in excess of that provided for on the forms - catch of more than five species, more than four biological samples - can be easily recorded by continuing onto additional forms. Duplicating items 1-39 on the catch form and items 1-28 on the biological sample form will uniquely identify the data.

In all cases, the collection forms are designed to facilitate direct entry onto electronic media (e.g. keypunch). To account for all standard media, an 80-column record size is used.

FIGURE 1. Effort data log/survey form.

1 Type (1)		2 Fisherman's License No.		8 Vessel Registration No.		16 Gear (2)	
17 Month Departure				19 Day Departure		21 Year Departure	
25 Month Return				27 Day Return		29 Year Return	
33 Time Search- Unit (4)				34 ing		36 Fish- ing	
Trip Dates (3)						Activity Time	
38 Latitude		41 N.or S		43 Longitude		44 N.or S	
47 No. Anglers, Hooks, Traps & Nets		49 Average Depth Fished		50		53	
Mid-Trip Position (5)						Gear (6)	
56 Type (7)		57 Quantity Units (8)		61 Trawl Width		64 Units (9)	
65 Trawling Speed		68 Units (10)		Bait Used (6)		Trawling (6)	

- 1 Type: 1 = daily log; 2 = weekly log; 3 = monthly log;
4 = market survey; 5 = vessel survey.
- 2 Gear: 1 = baitboat; 2 = handline; 3 = longline; 4 = trap;
5 = trawl; 6 = troll; 7 = recreational hook and line.
- 3 For one day trip use departure date.
- 4 Time unit: H = hour; D = day; W = week.
- 5 Noon or middle day if trip greater than one day.
- 6 Fill-in if applies to particular fishery.
- 7 Bait type: 1 = anchovy; 2 = mollie; 3 = sardine.
- 8 Weight units: P = pounds; K = kilograms; 1 = 5 pound scoop;
2 = 10 pound scoop.
- 9 Trawl width units: F = feet; M = meters.
- 10 Trawl speed units: M = miles/hr.; K = knots/hr.

FIGURE 2. Catch data log/survey forms.

1	2	8	16
Type	Fisherman License No.	Vessel Registration No.	Gear
①			②

17	19	21	25	27	29	33	36
Month	Day	Year	Month	Day	Year	Sighted	Fished
Departure						Return	
Trip Dates ③						Number Schools	

39
Catch Weight Units ④

Catch ⑤		
Species	No.	Weight
40		
48		
56		
64		
72		

- 1 Type: 1 = daily log; 2 = weekly log; 3 = monthly log;
4 = market survey; 5 = vessel survey, etc.
- 2 Gear: 1 = baitboat; 2 = handline; 3 = longline; 4 = trap;
5 = trawl; 6 = troll; 7 = recreational hook and line, etc.
- 3 For one day trip use departure date.
- 4 Catch weight units: P = pounds; K = kilograms; S = short tons;
L = long tons; M = metric tons, etc.
- 5 Species: 01 = blue marlin, ... (a species list)

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FIGURE 3. Sample biological sample data log/survey form.

1 Type ①	2 Fisherman License No.	8 Vessel Registration No.	16 Gear ②
---	--	--	--

17 Month	19 Day	21 Year	25 Species ③	27 Length 4	28 Weight 5
Date			Units		

Sample No.	Length	Weight	Sex (M-F)	Biological Sample (Y-N)
29				
40				
51				
62				

- 1 Type: 1 = daily log; 2 = weekly log; 3 = monthly log;
 4 = market survey; 5 = vessel survey, etc.
- 2 Gear: 1 = baitboat; 2 = handline; 3 = longline; 4 = trap;
 5 = trawl; 6 = troll; 7 = recreational hook and line, etc.
- 3 For one day trip use departure date.
- 4 Length units: M = millimeters; C = centimeters; N = meters;
 I = inches; F = feet, etc.
- 5 Weight units: G = grams; K = kilograms; P = pounds, etc.

5. SUMMARY AND CONCLUSIONS

This study began with a trip to interview agencies concerned with fishery catch and effort data collection and use in the Western Pacific Regional Fishery Management Council's area of interest - the American Samoa Office of Marine Resources, the Guam Aquatic and Wildlife Resources Division, the Hawaii Division of Fish and Game, the Northern Marianas Fishing Authority, the National Marine Fisheries Service - Honolulu Laboratory and the Council Executive Director's Office.

Results of the interview trip and of our assessment of western Pacific agency data needs, the degree to which current data collection activities satisfy needs and alternative formulations of a total management information system to satisfy Council needs are summarized as follows:

1. A total of 53 fisheries were identified in the five agency areas. Seventeen of these are of management interest to the Council (Table 2).
2. Council data needs are restricted to the following fisheries: troll, handline, pole and line and longline for billfish; handline, trap, line and trawl for bottomfish; traps for lobster; and submersible, trawl and hand gathering for precious coral (Table 4).
3. For data collection purposes, these fisheries are combined, when practical, within agency areas. For example, in American Samoa, the commercial/charter troll fishery is combined with the small boat troll fishery.
4. Collection systems, which can form the framework for a comprehensive Council system, exist in all areas. However, none of the present agency systems are adequate for Council needs and, in addition, the individual systems are not coordinated to provide a western Pacific management information system. Some catch data is being collected for all fisheries of interest to the Council. However, for many fisheries, there is no effort or inadequate effort being collected.
5. Recommended data collection systems fall into three general categories: vessel logbooks and/or periodic reporting by fishermen; periodic surveys and/or interviews with fishermen or dealers; and fish tickets completed by the first buyers to record the flow of fish through commercial channels. The merits and drawbacks of each system for each of the fishery area/units of concern were examined, then ranked according to cost and effectiveness (Table 8).
6. Data reduction alternatives considered included local agency reduction, central site reduction and combinations of local and central operations. The merits and drawbacks of each were

examined for each fishery/area unit, then ranked according to cost and effectiveness (Table 8).

7. Storage and retrieval systems were investigated. It is recommended that the central storage and retrieval system be located in Honolulu, utilizing the NMFS contract computer facilities (currently INFONET) at the NMFS Laboratory.
8. Three alternative Management Information Systems were developed by combining the alternative agency data collection and reduction methods.
9. The recommended system consists of the first ranked agency methods combined with a central storage and retrieval system based at NMFS Laboratory, Honolulu. The second and third alternative systems are variations of the recommended system.
10. The first ranked system is estimated to require the addition of 4.45 man-years' labor annually, allocated as follows: 1.65 man-years' labor to local agency staff for data collection; 1.10 man-years, divided between local agencies and the central site, for data reduction; and 1.70 man-years at the central site for storage and retrieval. The system requires the addition of the following data processing equipment: approximately 1.10 machine-years of data entry equipment, at both local and central sites, and 2.00 machine-years of file editing equipment located at the central site.
11. Systems could be operational within 12 months of introduction.
12. The needs of all area agencies for data collection forms can be met by three general forms - one each for effort, catch and biological data. Data can be entered (e.g. key punched) directly from these forms.

6. APPENDICES

6.1 FISHERY INFORMATION NEEDS - BY AGENCY

CONTENTS

- 6.1.1. Introduction
- 6.1.2. American Samoa Office of Marine Resources
- 6.1.3. Guam Aquatic and Wildlife Resources Division
- 6.1.4. Hawaiian Division of Fish and Game
- 6.1.5. Northern Marianas Fishing Authority
- 6.1.6. National Marine Fisheries Service

6.1.1. INTRODUCTION

The first objective of this report is to identify fishery data needs of the six western Pacific agencies, in that area of the central and western Pacific within the jurisdiction of the Council.

The various users of fishery information in American Samoa, Guam, Hawaii and the Northern Mariana Islands were initially polled as to their institutional objectives and biological data needed to fulfill those objectives. Results are summarized in Table 1.

Institutional objectives, as well as specific informational needs, are examined in detail below for each agency in turn. Those agencies primarily responsible for the collection of basic data - i.e., all except the Council - are discussed first; the Council, which is chiefly concerned with conclusions and recommendations derived from the synthesis and analysis of the basic data, is covered last.

6.1.2. AMERICAN SAMOA OFFICE OF MARINE RESOURCES

Fishery data collection activities in American Samoa by the Office of Marine Resources (OMR) are funded through the Dingle-Johnson Act. In addition, statistical information on catches of foreign longline vessels delivering to the area needed by the National Marine Fisheries Service, Honolulu, is collected by the Office of Marine Resources.

American Samoa consists of seven islands: Tutuila; Annu'u; the Manua group of Ta'u, Olosega and Ofu; Swains and Rose. Tutuila, the largest, is surrounded by a narrow fringing reef which is heavily fished by subsistence and recreational fishermen. The offshore banks and the outer islands have greater fishing area but they lie a considerable distance from Tutuila and few local vessels are sufficiently seaworthy to fish these areas.

Thirty thousand of the 35,000 total population of the Islands is concentrated on Tutuila. Local wind and sea conditions prevent small craft from operating anywhere except close to Tutuila. Thus, with the exception of the offshore tuna fleet based in Pago Pago, which ranges the south central Pacific, the bulk of fishing activity in American Samoa is subsistence and recreational in character.

Tables 12 and 13 show in detail the various pieces of catch/effort data that could usefully be gathered to fully describe American Samoa fishing activities. Table entries indicate the effort and catch/landing data to be collected from each operating unit (or a sample of operating units), in each fishery. For each

table, a number entered for a fishery (row) indicates that the indicated data item (column) could be usefully collected for that fishery. Entries are coded to indicated desired collection or compilation periodicity. The precise meaning of each code number is provided in footnote 1 on Table 4. Further, entries for data items deemed essential by the agency (i.e., the Office of Marine Resources in Tables 12 and 13) are indicated by underlining. This scheme is followed in all catch/effort tables.

The first effort data item - "effort description" - in Table 12 (and in all subsequent effort data tables in the report) is descriptive and as noted, is to be collected "by periodic survey." After initial collection, by survey techniques, supplemental vessel registration or fisherman licensing schemes, this data should be updated periodically, as personnel monitoring the fishery become aware of changes in measured data. Data encompassed by "effort description" are defined in the footnote of Table 3. It should be noted, however, that data encompassed by this data item may differ slightly by area - that is, from agency to agency - depending on agency requirements and collection capabilities.

As entries in Tables 12 and 13 indicate, monthly collection or compilation of most data items should be sufficient to fulfill OMR requirements. The only exceptions are the "effort description" item as noted above. Due to the limited scope of local fishing activities in American Samoa, essential data needs do not present too formidable a collection task.

Foreign tuna longlining activities, although based in American Samoa, are not included in Tables 12 and 13. Biological data describing these activities are not needed by the Office of Marine Resources, as all fishing takes place well outside American Samoan waters; these data needs with respect to foreign tuna longlining activities are addressed below under these two agencies.

6.1.3. GUAM AQUATIC AND WILDLIFE RESOURCES DIVISION

The island of Guam lies 3,300 nautical miles west of Honolulu and 1,500 miles east of Manila. Encompassing a land area of 209 square miles, Guam is the largest island in the western Pacific between Hawaii and the Philippines. The island is geographically part of the Marianas Island chain, but has been politically separate since 1898, the end of the Spanish-American War. Total population in 1970 was 85,000 persons, but increases since the census have probably pushed the population level closer to 100,000. Inhabitants and development are concentrated on the southern two-thirds of the island, primarily along the western coast.

Table 12. Fishing effort data needs, American Samoa Office of Marine Resources. Entries reflect desired data collection periodicity^{1/}. Underlined entries are essential data.

Fishery	Effort Data														
	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets	Bait type	Bait quantity used	No. gear sets	No. successful sets
Diving	7	4		4			4	4							
Handline															
Commercial	7		4				4	4			4				
Subsistence	7			4			4	4			4				
Shoreline															
Handpicking	7	4		4			4	4							
Hook and line	7	4		4			4	4							
Stationary nets, weirs	7						4								
Throw nets	7	4		4			4	4							
Traps	7						4	4		4	4	4			
Troll															
Commercial/charter	7		4				4	4			4				
Small boat	7			4			4	4			4				

^{1/} Symbols: See footnote 1, Table 4.

^{2/} "Effort description" encompasses such data as vessel/fishermen identification, vessel and fishermen numbers, vessel characteristics (owner's and captain's name, radio call sign, vessel length, beam, tonnage, engine size, fuel/bait/fish hold capacity, gear type and description, crew size, and port), other gear characteristics, port and landing/launching site characteristics, and possibly fishermen profile information.

Table 13. Fishery catch data needs, American Samoa Office of Marine Resources. Entries reflect desired data collection periodicity^{1/}. Underlined entries are essential data.

Fishery	Catch Data								
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition	Size composition (by species)
Diving			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	
Handline									
Commercial				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	4
Subsistence			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	
Shoreline									
Handpicking			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	
Hook and line			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	
Stationary nets, weirs				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Throw nets				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Traps			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	4
Troll									
Commercial/charter			<u>4</u> ^{2/}	<u>4</u> ^{3/}	<u>4</u>	<u>4</u>		<u>4</u>	4
Small boat			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	

^{1/} Symbols: See footnote 1, Table 4.

^{2/} Charter.

^{3/} Commercial.

Aquatic and Wildlife Resources Division (AWR) data collection activities in Guam are funded largely by the Federal Government through the Dingell-Johnson Act under a project to "survey Guam's fish population and fishing methods." The objective of this project, as shown in Table 1, are to accumulate information necessary to formulate effective management programs for the Island's fishery resources.

Present fishing activities in Guam are dominated by recreational and subsistence elements, and are limited in scope and magnitude. Data needs, like those for American Samoa, are thus relatively basic, as shown in Tables 14 and 15. As entries in Tables 14 and 15 indicate, monthly collection or compilation of nearly all data items will suffice. The only exceptions are "effort description," for which only periodic survey is necessary.

6.1.4 HAWAII DIVISION OF FISH AND GAME

The State of Hawaii is a chain of 132 islands near the center of the north Pacific Ocean, about 2,400 miles from San Francisco. The chain extends 1,523 miles from the island of Hawaii in the southeast to Kure Island in the northwest, and may be divided into three groups: the sand and coral islands of the northwest; rock islets in the center; and the eight major islands at the southeast end. The eight major islands - Hawaii, Oahu, Maui, Kahoolawe, Lanai, Molokai, Kauai and Niihau - comprise all except three square miles of the entire land area (6,425 square miles) and account for almost all of the chain's 750 miles of coastline. Of the state's over 850,000 inhabitants, about 82 percent are concentrated in Oahu, followed by the island of Hawaii (8 percent), Maui (6 percent) and Kauai (4 percent).

The guiding mandates of the Hawaii Division of Fish and Game (HFG) are to manage and assist in the development of aquatic resources under State jurisdiction^{1/}. In many ways, these objectives overlap, of course, but reliable information and data about past and present exploitive activities are a basic input to both intelligent management decisions and development planning.

Fishing activities in the Hawaiian islands are diverse - in the wide range of species taken and the variety of gear and techniques utilized - and at the same time, relatively small in scale, presenting a formidable data collection task. Tables 16 and 17 show in detail the various pieces of catch/effort data that could usefully be gathered to fully describe Hawaii's fishing activities.

^{1/} Seaward boundaries of State jurisdiction are not clearly defined - the issue is currently being argued legally.

Table 14. Fishing effort data needs, Guam Aquatic and Wildlife Resources Division. Entries reflect desired data collection periodicity.^{1/}
Underlined entries are essential data.

Effort Data											
Fishery	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets
											Bait type
											Bait quantity used
											No. gear sets
											No. successful sets
Inshore											
	Handpicking and spear (diving)	7		<u>4</u>		4	4				4 ^{2/}
	Hook and line	7		<u>4</u>		4	4				
	Net	7		<u>4</u>		4	4				
Offshore											
	Handline	7	4	<u>4</u>		4	4				4
	Spear (diving)	7		<u>4</u>		4	4				
	Troll	7		<u>4</u>		4	4				4
Ponds, weirs		6				4					

^{1/} Symbols: See footnote 1, Table 4.

^{2/} Gill net.

Table 15. Fishery catch needs, Guam Aquatic and Wildlife Resources Division. Entries reflect desired data collection periodicity.^{1/} Underlined entries are essential data.

Fishery	Catch Data								
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition	Size composition (by species)
Inshore									
Handpicking and spear (diving)			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	
Hook and line			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	
Net				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Offshore									
Handline			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	
Spear (diving)			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	
Troll			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	4 4
Ponds, weirs				<u>4</u>		<u>4</u>		<u>4</u>	

^{1/} Symbols: See footnote 1, Table 4.

Table 16. Fishing effort data needs, Hawaii Division of Fish and Game.
 Entries reflect desired data collection periodicity. 1/ Underlined entries
 are essential data.

	Effort Data														
Fishery	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets	Bait type	Bait quantity used	No. gear sets	No. successful sets
Diving															
	Aquarium	7	4	<u>4</u>		4	<u>4</u>								
	Spear, gathering	7	4	<u>4</u>		4	<u>4</u>								
Handline															
	Akule/opelu	7	4 ^{2/} <u>4</u> ^{3/}	4 ^{2/} <u>4</u> ^{2/}		4	<u>4</u> ^{3/}			4 ^{3/} <u>4</u> ^{3/}					
	Deepsea (bottomfish)	7		<u>4</u> ^{2/} <u>4</u> ^{2/}		4	<u>4</u> ^{3/}			4 ^{3/} <u>4</u> ^{3/}					
	Inshore (bottomfish)	7	4 ^{2/} <u>4</u>	<u>4</u>		4	<u>4</u>			4					
	Tuna	7	<u>4</u>			4	<u>4</u>			4 - 4					
	Longline ("ahi")	7				<u>1</u>	<u>1</u>			1	<u>1</u>	1	1		
Net															
	Akule	7				4 ^{5/} <u>4</u>	<u>4</u>								
	Bait <u>4</u> /	7				4	<u>4</u>	<u>4</u>						4	4
	Gill	7					<u>4</u>	<u>4</u>			4 ^{3/} <u>4</u>				
	Tangle (crab)	7					<u>4</u>	<u>4</u>			<u>4</u> ^{3/}				
	Trawl	7					<u>4</u>	<u>4</u>	4						
	Pole and line ("aku")	7				4	<u>4</u>	<u>4</u>			4	4	4		
Pond		7													
	Precious coral	7	4 ^{6/} <u>4</u>	4 ^{6/} <u>4</u>		4	<u>4</u>								
Shoreline															
	Handpicking	7	4	<u>4</u>		4	<u>4</u>								
	Hook and line	7	4	<u>4</u>		4	<u>4</u>								
	Throw nets	7	4	<u>4</u>		4	<u>4</u>								
Trap															
	Bottomfish	7				4	<u>4</u>			4	<u>4</u>				
	Crab	7				4	<u>4</u>				<u>4</u>				
	Lobster	7				4	<u>4</u>			4	<u>4</u>	4			
	Shrimp	7				4	<u>4</u>				<u>4</u>				
Troll															
	Commercial/charter	7				4	<u>4</u>				<u>4</u>				
	Small boat	7		4		4	<u>4</u>				<u>4</u>				

Table 16 (Cont.)

-
- 1/ Symbols: See footnote 1, Table 4.
 - 2/ Recreational.
 - 3/ Commercial.
 - 4/ Mainly tuna pole and line vessels
 - 5/ Including aerial search time.
 - 6/ Divers only.

Table 17. Fishery catch data needs, Hawaii Division of Fish and Game. Entries reflect desired data collection periodicity. 1/ Underlined entries are essential data.

Fishery	Catch Data							
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition Size composition (by species) Sex composition (by species)
Living								
Aquarium			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Spear, gathering			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Handline								
Akule/opelu			<u>4</u> ² / <u>4</u> ³	<u>4</u> ³ / <u>4</u>	<u>4</u>		<u>4</u>	
Deepsea (bottomfish)			<u>4</u> ² / <u>4</u> ³	<u>4</u> ³ / <u>4</u>	<u>4</u>		<u>4</u>	
Inshore (bottomfish)			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Tuna			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	4 4
Longline ("ahi")			<u>1</u>	<u>1</u>	<u>1</u>	1	<u>1</u>	4 4
Net								
Akule	4	4		<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Bait	4	4		<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Gill				<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Tangle (crab)			<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Trawl				<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Pole and line ("aku")	4	4		<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	4
Pond				<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Recreational coral				<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Shoreline								
Handpicking			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Hook and line			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Throw nets				<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Trap								
Bottomfish				<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Crab				<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Lobster			<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	4 4
Shrimp				<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	
Toll								
Commercial/charter			<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	4 ⁴ /4 ⁴
Small boat			<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	

Symbols: See footnote 1, Table 4.
 / Recreational fishery only.
 / Commercial fishery.
 / Billfish only.

6.1.5. NORTHERN MARIANAS FISHING AUTHORITY

The Northern Mariana Islands consists of 13 single islands and one group (Maug Island) of three small islands which extend in a chain some 300 miles long, from Farallon de Pajaros in the north to Rota Island in the south. Total land surface is approximately 183 square miles, two-thirds of which is made up of the three principal islands: Saipan, Tinian and Rota. These islands also account for all but about 150 of the total population of approximately 15,000 persons; over 85 percent alone live on Saipan, the District Center. Saipan is the only island with a sizeable lagoon, which extends almost the entire length of the western side of the island. The bulk of Saipan's population is concentrated along the southwestern shore.

Government involvement in fishery matters is a relatively recent phenomenon in the Northern Marianas. Additionally, at the time of the field work, a complete restructuring of the government was under study in preparation for the impending change in political status of the Islands. Consequently, government policy and goals - even the entity of the implementing agency - with respect to fishery data collection were in the process of reformulation during late 1977. Discussions with the principals in government concerned with fishery matters, however, indicated that fishery data are broadly conceived as needed for resource conservation purposes, for development planning, for regulatory purposes (aimed primarily at foreign fishing activity) and to provide a basis for the Fishing Authority (NMFA) or whatever agency supercedes it - to make informed decisions on fishermen loan requests.

Like Guam, fishing activities in the Northern Marianas are dominated by recreational and subsistence elements; activities, however, are even more limited in magnitude than in Guam. Data requirements are thus similarly basic, as indicated in Tables 18 and 19.

Table entries indicate the various catch and effort information required of operating units in each fishery. Catch/effort data is difficult and expensive to collect from recreational/subsistence fishermen; quarterly estimate of these data for inshore activities (which are dominated by the recreational/subsistence element), as well as for fish trap and weir operations, would suffice. Additionally, quarterly estimation of all effort data and most catch data for the small boat offshore fishery is adequate. Compilation of data relating to billfish catches in the offshore fishery would be desirable, however. Catch/effort information on the small commercial line fishery should also be collected monthly.

Essential data needs of the Fishing Authority are not great due to the limited scope and magnitude of current fishing activities in the Islands.

Table 18. Fishing effort data needs, Northern Marianas Fishing Authority.
 Entries reflect desired data collection periodicity.^{1/} Underlined entries
 are essential data.

Fishery	Effort Data														
	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets	Bait type	Bait quantity used	No. gear sets	No. successful sets
Commercial line	7						4	4			4				
Small scale															
Inshore	7						5	5							
Offshore	7			5			5	5			5				
Traps	7						5	5			5				
Weirs	7														

^{1/} Symbols: See footnote 1, Table 4.

Table 19. Fishery catch data needs, Northern Marianas Fishing Authority. Entries reflect desired data collection periodicity.^{1/} Underlined entries are essential data.

Fishery	Catch Data							
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition
								Size composition(by species)
								Sex composition(by species)
Commercial line			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Small scale								
Inshore			<u>5</u>	<u>5</u>	<u>5</u>		<u>5</u>	
Offshore			<u>5</u>	<u>5</u>	<u>5</u>		<u>5</u>	
Traps			<u>5</u>	<u>5</u>	<u>5</u>		<u>5</u>	
Weirs			<u>5</u>	<u>5</u>	<u>5</u>		<u>5</u>	

^{1/} Symbols: See footnote 1, Table 4.

6.1.6 NATIONAL MARINE FISHERIES SERVICE

The mandate of the National Marine Fisheries Service (NMFS), is a broad one, encompassing fishery resource research, utilization and management. NMFS is charged with carrying out basic and applied research which will support wise development and provide a basis for intelligent management decisions. The agency is also to assist industry and State/Commonwealth/Territory fishery agencies in their efforts to stimulate development and optimal commercial and recreational utilization of fishery resources. Under the Fisheries Conservation and Management Act of 1976, the NMFS was given the responsibility of assisting the regional management councils (set up under the Act) in the formulation of fishery management plans, as well as the task of implementing the finalized plans. The data needs of the Honolulu Laboratory thus relate primarily to research and management responsibilities.

Research and management interests of the Honolulu Laboratory currently focus on a few key fisheries and species of the region. Pelagics, especially tuna and billfish, are the prime species of interest to the Laboratory. Billfish information requirements, however, relate primarily to support of the Council management responsibilities, and are thus identified and discussed under that agency. Similarly, Northwest Hawaiian lobster and bottomfish data needs, while of importance to NMFS, relate primarily to the Council and HF&G jurisdictional responsibilities and are consequently examined under those agencies. NMFS data requirements for tuna fisheries, both domestic and foreign, are specified in detail in Tables 20 and 21. as are data needs in the foreign precious coral and bottomfish fisheries. The latter two fisheries, while part of the management responsibilities of the Council, are clearly within the mandate of NMFS to collect foreign fishery data.

As indicated in the following tables, the bulk of catch/effort information on domestic tuna fisheries is desired "by trip." Monthly collection or compilation of the appropriate foreign fishery data is adequate.

Table 20. Fishing effort data needs, National Marine Fisheries Service, Honolulu Laboratory. Entries reflect desired data collection periodicity.^{1/} Underlined entries are essential data.

Fishery	Effort Data										
	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets
											Bait type
											Bait quantity used
											No. gear sets
											No. successful sets
Domestic Tuna ^{2/}											
Pole and line	7				1	1	1	1			1
Purse seine	7				1	1	1	1			1
Troll	7						1	1			1
Foreign											
Bottomfish											
Line	7						4	4			-4
Trawl	7						4	4	4	4	
Precious coral	7						4	4	4		
Tuna pole and line	7					4	4	4			4
Tuna longline	7						4	4		4	4

^{1/} Symbols: See footnote 1, Table 4.

^{2/} Domestic tuna vessels fishing in central or western Pacific on which statistics are not collected by State/Commonwealth/Territorial agencies.

Table 21. Fishery catch data needs, National Marine Fisheries Service, Honolulu Laboratory. Entries reflect desired data collection periodicity.1/ Underlined entries are essential data.

Fishery	Catch Data								
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition	Size composition (by species)
Domestic tuna									
Pole and line	<u>1</u>	<u>1</u>		<u>1</u>	<u>1</u>	<u>1</u>		<u>1</u>	4
Purse seine	<u>1</u>	<u>1</u>		<u>1</u>	<u>1</u>	<u>1</u>		<u>1</u>	4
Troll				<u>1</u>	<u>1</u>	<u>1</u>		<u>1</u>	4
Foreign									
Bottomfish									
Line				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Trawl				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Precious coral				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Tuna pole and line	<u>4</u>	<u>4</u>		<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Tuna longline			<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	4 4

/ Symbols: See footnote 1, Table 4.

6.2 COMPARISON OF INFORMATION NEEDS AND CURRENT COLLECTION
ACTIVITIES - BY AGENCY

CONTENTS

- 6.2.1. Introduction
- 6.2.2. American Samoa Office of Marine Resources
- 6.2.3. Guam Aquatic and Wildlife Resources Division
- 6.2.4. Hawaii Division of Fish and Game
- 6.2.5. Northern Marianas Fishing Authority
- 6.2.6. National Marine Fisheries Service

6.2.1. INTRODUCTION

The second objective of this report is to compare fishery information needs to data presently produced by existing fishery data collection systems in the region in order to identify areas where data availability falls short of information requirements. Data collection is described for all fisheries whether or not individual fisheries are those for which the Council needs data (focus fisheries).

Each agency is again examined in turn, utilizing the same matrix format presented in Appendix 6.1. As in Tables 12-21, an entry in a column indicates that information could be usefully collected for the fishery represented by the row; for data deemed essential, entries are again underlined. Entry coding, however, differs.

Instead of periodicity, entries indicate the degree to which information needs - as specified in the appropriate table in Appendix 6.2 - are fulfilled by current data collection activities. Footnote 1 of Table 6 provides a precise definition of the entry code. In many cases, however, the degree to which needs are satisfied cannot be neatly quantified because, for example, the complexity of data needs and present collection realities, or a lack of sufficient knowledge about current data collection techniques. The adequacy and shortcomings of currently available data and collection systems for these cases are discussed in the accompanying narrative.

6.2.2 AMERICAN SAMOA OFFICE OF MARINE RESOURCES

Tables 22 and 23 compare present OMR fishery data collection activities with information requirements defined in Appendix 6.1. Only activities of direct interest to the Office, i.e., those related to local American Samoa fisheries, are addressed here. The adequacy of the data collection system for the foreign long-line fishery, for which catch and effort information are of prime interest to the NMFS and Council, is addressed below (in this section) under those agencies; this system is funded and directed by NMFS.

A fish ticket system has been introduced to obtain information on the catches of trollers, handliners and longliners delivered to the Tutuila market. The lack of information on the proportion of total catches in fisheries covered by the current system is reflected in the "S" entries on Table 23 for line and troll fisheries. Additionally, for some fisheries, the species composition of deliveries to the market is unclear.

Table 22. Degree to which effort data needs of the American Samoa Office of Marine Resources (Table 13) are satisfied. Entries reflect the degree to which current collection activities satisfy needs.^{1/} Underlined entries are essential data.

Fishery	Effort Data														
	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets	Bait type	Bait quantity used	No. gear sets	No. successful sets
Diving	S	S		N											
Line															
Commercial	S		S			S	N				N				
Subsistence	S			N		N	N	N			N				
Shoreline															
Handpicking	S	2		N		S	2								
Hook and line	S	2		N		S	2								
Stationary nets, weirs	N					N									
Throw nets	S	2		N		S	2								
Traps	N					N	N			N	N	N			
Troll															
Commercial/charter	S		N			N	N				N				
Small boat	S			N		N	N				N				

^{1/} Symbols: See footnote 1, Table 6.

Table 23. Degree to which catch data needs of the American Samoa Office of Marine Resources (Table 14) are satisfied. Entries reflect the degree to which current collection activities satisfy needs.^{1/} Underlined entries are essential data.

Fishery	Catch Data							
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition
Diving								
Line	<u>S</u>				<u>N</u>	<u>N</u>		<u>N</u>
Commercial				<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>
Subsistence	<u>N</u>				<u>N</u>	<u>S</u>		<u>S</u> N
Shoreline								
Handpicking	<u>2</u>				<u>2</u>	<u>2</u>		<u>2</u>
Hook and line	<u>2</u>				<u>2</u>	<u>2</u>		<u>2</u>
Stationary nets, weirs				<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>
Throw nets				<u>2</u>	<u>2</u>	<u>2</u>		<u>2</u>
Traps	<u>N</u>				<u>N</u>	<u>N</u>		<u>N</u> N
Troll								
Commercial/charter	<u>2</u>		<u>2</u>		<u>N</u>	<u>2</u>		<u>2</u> N
Small boat	<u>S</u>				<u>S</u>	<u>S</u>		<u>S</u>

^{1/} Symbols: See footnote 1, Table 6.

Data describing fishing effort and areas of capture are not currently collected. However, some data on "effort description" is yielded by the Coast Guard boat registration program covering vessels over five tons gross weight.

Data describing catch and effort in both small craft sport troll and small trap fisheries are presently not collected.

For the shore subsistence fisheries, considerable information has been obtained on total effort and catch through twice-weekly surveys from the road system of Tutuila. These surveys, due to budget and personnel limitations, do not yield certain essential effort data - such as "number of angler trips," and produce only broadly descriptive data on and partial coverage of other elements of catch and effort. Handpicking, pole and line, throw net and diving activity on the other islands and parts of Tutuila are not covered by present data collection activities.

Stationary nets and weirs, another shoreline activity associated with village fisheries, have not yet been surveyed.

In summary, data collection coverage of the major local fishing operations remains incomplete, but has improved significantly in the recent past; coverage of the more difficult inshore subsistence activities is still poor.

6.2.3 GUAM AQUATIC AND WILDLIFE RESOURCES DIVISION

Tables 24 and 25 compare present AWR fishery data collection activities in Guam with information requirements formulated for the Island in Appendix 6.1.

Guam Department of Public Safety registration requirements (for all powered vessels over ten horsepower) provide a fragmentary picture of fishing vessel numbers in Guam. Registration information, however, does not indicate vessel use; the precise number of registered fishing vessels is thus far not known. Additionally, an unknown number of trailered power vessels, as well as all unpowered vessels, go unregistered. Registration appears to be a one-time requirement (for each owner); annual changes must be estimated. Registration information provides the bulk, but not all, of needed vessel data for the larger (moored) vessels.

As there are presently only two ports where vessels may be moored, AWR Division personnel are able to keep fairly close tabs on the numbers of moored fishing vessels by port, as well as get a good idea of the numbers of the most active trailered fishing vessels.

Table 24. Degree to which effort data needs of the Guam Aquatic and Wildlife Resources Division (Table 15) are satisfied. Entries reflect the degree to which current collection activities satisfy needs.1/ Underlined entries are essential data.

Effort Data															
Fishery	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets	Bait type	Bait quantity used	No. gear sets	No. successful sets
Inshore															
Handpicking and spear (diving)	S		4			3		3							
Hook and line	S		4			4		4							
Net	S		4			4		3			4 ²				
Offshore															
Handline	S		2			2		2			2				
Spear (diving)	S	2		2		2		2							
Troll	S			2		2		2			2				
Ponds, weirs	S							N							

1/ Entry Symbols: See Footnote 1, Table 6.

2/ Gill nets only.

Table 25. Degree to which catch data needs of the Guam Aquatic and Wildlife Resources Division (Table 16) are satisfied. Entries reflect the degree to which current collection activities satisfy needs. 1/ Underlined entries are essential data.

Fishery	Catch Data							
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition Size composition(by species) Sex composition(by species)
Inshore								
Handpicking and spear(diving)			<u>3</u>		<u>3</u>	<u>3</u>		<u>2</u>
Hook and line			<u>4</u>		<u>4</u>	<u>4</u>		<u>2</u>
Net				<u>3</u>	<u>3</u>	<u>3</u>		<u>2</u>
Offshore								
Handline			<u>2</u>	<u>2</u>	<u>2</u>	<u>2</u>		<u>2</u>
Spear (diving)			<u>2</u>		<u>2</u>	<u>2</u>		<u>2</u>
Troll			<u>2</u>		<u>2</u>	<u>2</u>		<u>2</u> U U
Ponds, weirs				<u>4</u>		<u>4</u>		<u>4</u>

/ Entry Symbols: See Footnote 1, Table 6.

As there is no requirement for the licensing of fishermen, their exact numbers are unknown. Estimates are made monthly of the numbers of participants for each gear type, as part of regular monthly creel censuses (see below); these estimates do not account for double counting, however. Some other basic effort description data are also provided by the creel censuses.

Inshore fishing activities are surveyed by a two-day-per-month creel census (interview) by Division personnel; offshore activities are covered by a four-day-per-month survey (interview) at Agana Boat Basin. The resulting data is analyzed, producing monthly effort estimates by gear type, as well as monthly catch estimates by major species. A voluntary daily catch record (essentially a log), to be submitted by cooperating offshore fishermen, is planned.

The chief shortcoming of the system is that activities are surveyed on only two (inshore) or four (offshore) days a month. This sample size may not be sufficient to assure acceptable accuracy of estimates. Additionally, coverage is not consistent for all fisheries. Of the two boat basins and the five or six other launch sites, only Agana Basin is surveyed (covering an estimated 50 percent of offshore activity).

Coverage of inshore spear fishing and handpicking activities is weakest, as these fishermen are not as accessible to interviewers as other inshore fishermen. Data describing gill netting effort in more detail (set duration, number of nets and depth of set) is not collected.

Data collection activities with respect to fish weir operations yield information on the number, location and size of each weir and catches by species, but no data describing fishing time.

Present survey techniques yield estimates of a large portion of required catch/landing information. As mentioned previously, the chief shortcoming is that a reliable species breakdown of catches is not available for inshore activity due mainly to problems with species identification by survey personnel - except in the seasonal net fishery for rabbitfish (siganids); additionally, current estimates of catch volumes are thought to be suspect due to problems in converting fish numbers to weights. Difficulties in sampling inshore handpickers and spear fishermen appear to indicate catch estimates for this activity are less reliable than for other inshore activities.

Present survey techniques utilized in the offshore fishery cover only a portion of these activities (those out of Agana Boat Basin). The resulting monthly estimates of catch volume, by gear type, thus fall short of needs in coverage. Information on catch-by-species, area of catch and size by species is also collected during the regular surveys of Agana Boat Basin, but survey techniques must be improved (and coverage expanded) before these data will fulfill needs.

6.2.4 HAWAII DIVISION OF FISH AND GAME

Tables 26 and 27 compare present catch/effort data collection activities in the Hawaiian Islands with information requirements as formulated in Appendix 6.1. While a sophisticated data collection system is operated by HF&G to collect much biological data on commercial catches - i.e., those catches which are sold by the fishermen - there is no system to collect similar information on recreational/subsistence activities on a regular basis. Recreational/subsistence activities clearly dominate shoreline, spear and troll fishing activities, and are a major element in most other activities. Only pole and line, coral, aquarium, deepsea handline, longline, ika-sibi, bait, akule net, trawl and selected trap fisheries are clearly dominated by commercial interests. With few exceptions, however, Hawaiian fisheries are a mixture of commercial, recreational and subsistence elements.

Commercial fishermen are required to be licensed and submit monthly reports on effort and catches associated with their commercial activities. However, while fishermen in certain key fisheries, such as the inshore handline, troll and handpicking and gathering fisheries, hold fishing licenses and regularly submit monthly fish catch reports to HF&G reporting on their commercial activity, reported effort and catch/landing information are thought to cover only a small portion of total effort expended and catches. These complexities make tabular evaluation of current data collection activities and quantification of the degree to which identified needs are satisfied by current collection activities quite difficult. Consequently, Tables 26 and 27 represent primarily an evaluation of current data collection activities relative to commercial activities.

Data availability for those clearly commercial fisheries is best. Specialized, separate monthly report forms are utilized in pole and line, longline, baitfish, aquarium and pond fisheries. The entries in Tables 26 and 27 clearly reflect the degree to which effort and catch/landing data needs are met in each of these fisheries. The solitary large-scale precious coral harvester in the Islands reports required information to NMFS and HF&G on a confidential basis. The remainder of the commercially oriented fisheries, tuna handline, deepsea handline, trawl, akule net, NW lobster, bottomfish and shrimp trap - report effort and catches monthly on a generalized Fish Catch Report form. In the deepsea handline and NW lobster fisheries, "S" entries reflect the fact that data gathered on a trip basis are collected only for some trips (on a sampling basis by NMFS).

The charter troll, akule/oeplu handline, crab tangle net and bottomfish trap fisheries all embrace sizeable commercial and recreational/subsistence elements. Only catch/effort data where catches are sold are reported. This incompleteness of coverage is reflected in the "S" entries for data requirements in these fisheries.

Table 26. Degree to which effort data needs of the Hawaii Division of Fish and Game (Table 17) are satisfied. Entries reflect the degree to which current collection activities satisfy needs. 1/ Underlined entries are essential data.2/

Effort Data															
Fishery	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished(dragged,pond)	Depth gear set	No.hooks/traps/lines/nets	Bait type	Bait quantity used	No. gear sets	No. successful sets
Diving															
Aquarium	S	S		<u>N</u>		S	<u>N</u>								
Spear, gathering	S			<u>N</u>		S	<u>N</u>								
Handline															
Akule/opelu	S	<u>N</u> ^{4/}	<u>N</u> ^{3/}	<u>N</u> ^{4/}		S	<u>N</u>			<u>S</u> ^{3/}	<u>N</u> ^{3/}				
Deepsea (bottomfish)	S			<u>N</u>		<u>S</u> ^{3/}	<u>N</u>			<u>S</u> ^{3/}	<u>N</u> ^{3/}				
Inshore (bottomfish)	S	<u>N</u> ^{4/}		<u>N</u>		<u>N</u>	<u>N</u>				<u>N</u>				
Tuna	S		<u>S</u>			S	<u>N</u>			N	N				
Longline ("ahi")	S					<u>N</u>	<u>N</u>			N	<u>S</u>	5	5		
Net															
Akule	S					N	<u>S</u>	<u>N</u>							
Bait	N					N	<u>S</u>	<u>S</u>						N	N
Gill	N						<u>N</u>	<u>S</u>			<u>N</u> ^{3/}				
Tangle (crab)	S						<u>S</u>	<u>S</u>			<u>N</u> ^{3/}				
Trawl	S						<u>S</u>	<u>N</u>	N						
Pole and line ("aku")	S					N	<u>S</u>	<u>N</u>			S	5	5		
Pond	4														
Precious coral	5	<u>N</u> ^{5/}	<u>S</u> ^{6/}	<u>N</u> ^{5/}			<u>S</u> ^{6/}	<u>S</u> ^{6/}							
Shoreline															
Handpicking	N	N		<u>N</u>		S	<u>S</u>								
Hook and line	N	N		<u>N</u>		N	<u>N</u>								
Throw nets	N	N		<u>N</u>		N	<u>N</u>								
Trap															
Bottomfish	S						<u>S</u>	<u>N</u>		S	S				
Crab	S						<u>S</u>	<u>S</u>			<u>N</u>				N
Lobster	S						<u>S</u>	<u>N</u>		S	<u>S</u>	S			
Shrimp	S						<u>N</u>	<u>N</u>			<u>N</u>				
Troll															
Commercial charter	S						<u>S</u>	<u>S</u>			<u>N</u>				
Small boat	S			S			<u>S</u>	<u>S</u>			<u>N</u>				

1/ Symbols: See footnote 1, Table 6.

2/ This table evaluates primarily current data collection activities relative to commercial activities - i.e. those in which catches are sold; there is presently no system to collect data on recreational and subsistence fish activities on a regular basis. See text.

3/ Commercial.

4/ Recreational.

5/ Divers only.

6/ Large scale commercial operation only.

Table 27. Degree to which catch data needs of the Hawaii Division of Fish and Game (Table 18) are satisfied. Entries reflect the degree to which current collection activities satisfy needs.^{1/} Underlined entries are essential data.^{2/}

Catch Data									
Fishery	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition	Size composition (by species)
Diving									
Aquarium			<u>S</u>		<u>S</u>	<u>S</u>		<u>S</u>	
Spear, gathering			<u>S</u>		<u>S</u>	<u>S</u>		<u>S</u>	
Handline									
Akule/opelu			<u>N</u>	<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>	
Deepsea (bottomfish)			<u>N</u>	<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>	
Inshore (bottomfish)			<u>S</u>		<u>S</u>	<u>S</u>		<u>S</u>	
Tuna			<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	N N
Longline ("ahi")			<u>S</u>	<u>4</u>	<u>4</u>	<u>4</u>	N	<u>4</u>	N N
Net									
Akule	N	N		<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Bait	N	N		<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>	
Gill				<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>	
Tangle (crab)			<u>N</u>	<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Trawl				<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>	
Pole and line ("aku")	N	N		<u>S</u>	<u>4</u>	<u>S</u>		<u>S</u>	N
Pond				<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>	
Precious coral				<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>	
Shoreline									
Handpicking			<u>S</u>		<u>S</u>	<u>S</u>		<u>S</u>	
Pole and line			<u>N</u>		<u>N</u>	<u>N</u>		<u>N</u>	
Throw nets				<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>	
Trap									
Bottomfish				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Crab				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Lobster			<u>S</u>	<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	S S
Shrimp				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Troll									
Commercial/charter			<u>S</u>	<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>	N N
Small boat			<u>S</u>	<u>S</u>	<u>S</u>	<u>S</u>		<u>S</u>	

^{1/} Symbols: See footnote 1, Table 6.

While many effort and catch data needs of commercial fisheries are indicated as essentially fulfilled ("5" entries) by the present collection system, without exception quality problems exist with all presently available data which cannot be evaluated within the context of Tables 28 and 29. These problems relate to non-fulfillment by fishermen of reporting (for example "area fished"), poorly filled out forms (some fishermen do not have a good command of the English language) and timeliness.

6.2.5. NORTHERN MARIANAS FISHING AUTHORITY

Tables 28 and 29 compare present NMFA fisheries data collection activities with information requirements as formulated in Appendix 6.1.

A beginning has been made in collecting fishermen and vessel numbers; fishermen cooperative records (the co-op is managed by the Fishing Authority) yield these data for co-op members and for fishermen selling catches through the co-op retail outlet. Numbers of non-co-op fishermen and recreational/subsistence fishermen are unknown as no fishermen are licensed in the Islands. Vessel registration requirements of the Port Director of Saipan yield data on powered vessels; however, not all powered vessels are in fact registered, and no registration requirements exist for non-powered vessels. Numbers in this latter group are thus unknown. Registration requirements also yield the bulk of required vessel data (length, horsepower, etc.), but only for these vessels currently registered.

Little data are presently collected describing inshore catches - these activities are almost exclusively recreational/subsistence in character. Although a permit system exists for fish weir (trap) operators, no catch data are apparently gathered on these facilities. Limited data are available on the volume and distribution of off-shore catches through co-op records (most co-op members utilize boats, and are thus assumed to be primarily offshore fishermen). A monthly survey of fish retail outlets by the Fishing Authority Manager yields a monthly estimate of fish catches reaching commercial channels, as well as some information on fish distribution (almost all local catches that reach commercial channels go to the fresh market); the bulk of fish reaching commercial channels are thought to be of offshore origin, but some fish trap production and catches in the commercial line fishery also reach local commercial channels.

Operators of the one-two commercial line vessels fishing out of Saipan report their catches - by major species group - to the Fishing Authority Manager monthly. Volume of these catches exported - by major species group - are also reported.

Thus, an impressive beginning has been made by the Fishing Authority in collecting useful catch/landing information, but improvements are still required, as indicated in Table 29. The more difficult effort information remains largely uncollected to date (Table 28).

Table 28. Degree to which effort data needs of the Northern Marianas Fishing Authority (Table 19) are satisfied. Entries reflect the degree to which current collection activities satisfy needs.^{1/} Underlined entries are essential data.

Fishery	Effort Data														
	Effort description ^{2/}	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets	Bait type	Bait quantity used	No. gear sets	No. successful sets
Commercial line	S						N	N			N				
Small scale															
Inshore	N			N			N	N							
Offshore	S			N			N	N			N				
Traps	N						N	N			N				
Weirs	S														

^{1/} Symbols: See footnote 1, Table 6.

Table 29. Degree to which catch data needs of the Northern Marianas Fishing Authority (Table 20) are satisfied. Entries reflect the degree to which current collection activities satisfy needs.^{1/} Underlined entries are essential data.

Fishery	Catch Data							
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition Size composition (by species) Sex composition (by species)
Commercial line				<u>S</u>	<u>N</u>	<u>S</u>		<u>S</u>
Small scale								
Inshore			<u>S</u> <u>S</u>		<u>N</u>	<u>S</u>		<u>S</u> <u>S</u>
Offshore			<u>S</u>		<u>N</u>	<u>S</u>		<u>S</u> <u>S</u>
Traps			<u>S</u>		<u>N</u>	<u>S</u>		<u>S</u>
Weirs				<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>

^{1/} Symbols: See footnote 1, Table 6.

6.2.6 NATIONAL MARINE FISHERIES SERVICE

Tables 30 and 31 compare NMFS data collection activities with information requirements as listed in Appendix 6.1.

NMFS data requirements relative to domestic tuna baitboat and longline activity are largely filled, with the exception of several key data items. Requirements for domestic tuna purse seine and troll fisheries, as indicated, are for the most part, unsatisfied. (Purse seine data needs relate to the growing number of United States vessels, almost always home ported outside the region, which are fishing the central and western Pacific and occasionally call or unload at American Samoa and Hawaii.)

With respect to foreign fishing activity, the NMFS has prime responsibility for data collection. As indicated in the tables, data presently available describing these activities are meager, with the exception of information collected on foreign longline activity centered in American Samoa. All data on other foreign fishing activity in the contract region presently do not fulfill requirements. What data are available - with the exception of American Samoa activity - become accessible only after considerable lag time.

Table 30. Degree to which effort data needs of the National Marine Fisheries Service, Honolulu Laboratory (Table 21) are satisfied. Entries reflect the degree to which current collection activities satisfy needs.^{1/} Underlined entries are essential data.

Fishery	Effort Data										
	Effort description ^{2/}	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets
											Bait type
											Bait quantity used
											No. gear sets
											No. successful sets
Domestic tuna ^{2/}											
Pole and line	U				U	U	U	U		U	U
Purse seine	U				U	U	U	U			U
Troll	U						U	U		U	
Foreign											
Bottomfish											
Line	N						N	N			N
Trawl	N						N	N	N	N	
Precious coral	N						N	N	N		
Tuna longline	4						4	4		N	4
Tuna pole and line	N					N	N	N			N

^{1/} Symbols: See footnote 1, Table 6.

^{2/} See Footnote 3, Table 10. There have been occasional exploratory fishing ventures into the area but no permanent fishery and no permanent data collection system established. Any data collection is ad hoc, hence the "U" entries.

Table 31. Degree to which catch data needs of the National Marine Fisheries Service, Honolulu Laboratory (Table 22) are satisfied. Entries reflect the degree to which current collection activities satisfy needs.^{1/} Underlined entries are essential data.

Fishery	Catch Data								
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition	Size composition (by species)
Domestic tuna									
Pole and line	<u>C</u>	<u>C</u>		<u>C</u>	<u>C</u>	<u>C</u>		<u>C</u>	<u>C</u>
Purse seine	<u>C</u>	<u>C</u>		<u>C</u>	<u>C</u>	<u>C</u>		<u>C</u>	<u>C</u>
Troll				<u>C</u>	<u>C</u>	<u>C</u>		<u>C</u>	<u>C</u>
Foreign									
Bottomfish									
Line				<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>	
Trawl				<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>	
Precious coral				<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>	
Tuna pole and line	<u>N</u>	<u>N</u>		<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>	
Tuna longline			<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	<u>S</u>

^{1/} Symbols: See footnote 1, Table 6.

6.3 ALTERNATIVE MANAGEMENT INFORMATION SYSTEMS - BY AGENCY

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6.3.1 INTRODUCTION

The third objective of this report is to develop alternative Council-oriented management information systems defined in Section 3 as composed of three parts - data collection, data reduction and storage and retrieval.

Alternative ways of collecting and reducing data are developed below for each agency and summarized in Section 3. Storage and retrieval options are discussed in Section 3.

After system part alternatives are developed, benefits and costs of alternatives are discussed and ranked according to least cost. Both quantitative and non-quantifiable, qualitative features of proposed alternatives are contrasted in order to rank alternatives for each system component.

Quantitative features include man-years and machine-years necessary to implement an alternative. For purposes of comparison, it is assumed that the dollar-cost of a man-year of labor of a particular type is equivalent in all areas discussed, similarly the dollar-cost of a machine-year of equivalent pieces of equipment. Additionally, it is assumed that all costs accrue to the Council.

Non-quantifiable or qualitative features include such considerations as political and physical feasibility and compatibility of proposed alternatives with existing activities.

Where possible, alternative assessments for each system part are summarized in a ranked list. This quantitative ranking is modified, as appropriate, by qualitative considerations. The results of ranking are summarized in Section 3.

6.3.2 DATA COLLECTION - BY AGENCY

6.3.2.1 AMERICAN SAMOA OFFICE OF MARINE RESOURCES

The only local fisheries of concern to the Council are the troll fisheries. Samoan troll fisheries are prosecuted by a handful of boats fishing mostly from Pago Pago Harbor and are of Council interest because of the small catches of billfish^{1/}. The few commercial/charter trollers land more billfish than the smaller trollers, as they range farther and can handle larger fish. Of the few billfish landed, most do not enter commercial channels but are retained by fishermen.

^{1/} Several other species are grouped under "billfish" for Council purposes: wahoo, mahimahi and pelagic sharks.

Coast Guard vessel documentation yields limited "effort description" information. There is no logbook collection system focused on Samoan troll fisheries. A fish ticket system is operative at one market on Tutuila and yields information on billfish, wahoo and mahimahi landings when those species go through that particular market.

Tables 32 and 33 indicate catch and effort data requirements of both the Council and the Office of Marine Resources (OMR), with respect to the Samoan troll fisheries. Entries reflect the specific data items desired, their priority and necessary collection periodicity. Council requirements pertain only to billfish catch and effort. OMR needs, on the other hand, relate to catch and effort associated with the fishery as a whole. Table entries indicate other contrasts in Council and OMR data needs, but only the differences in priority attached to certain data items are likely to cause any conflicts between Council and OMR requirements.

As indicated in the tables, Council needs are not fulfilled by the existing American Samoa data collection activities.

Approaches to upgrading the present system are:

A LOGBOOK SYSTEM

A permanent logbook would be produced and distributed among troller fishermen by an OMR staff member responsible for the program. Program objectives and information requirements would be explained to fishermen when logs were distributed. Twice monthly the OMR staff member would circulate among fishermen to extract information from completed logs, obtain missing data by interview and offer advice on improving future logbook entries. Logbook collection procedures would have to be based on a voluntary compliance, as fishermen are not licensed in American Samoa. Due to the small number of trollers and their concentration at Pago Pago, such a system would require only .15 man-years of OMR staff time yearly.

SURVEY/INTERVIEW SYSTEM

The required information on billfish activity by local trollers could also be gathered by survey techniques. The small number of boats, concentrated at Pago Pago, should enable an OMR biologist to interview all troll fishermen once a week at a cost of only .25 man-years per year. Little additional time would probably be needed to concurrently gather information on offshore fishing activity.

FISH TICKET SYSTEM

Troll billfish catches are quite small, and few are sold by fishermen; most are retained because of the recreational nature of the fishery. Therefore, a fish ticket system will not generate the required information on catch.

Table 32. Western Pacific Regional Fishery Management Council and Samoa effort data needs and the degree to which current Samoa collection fulfills Council needs. 1/

Fishery	Effort Data										
	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets
Commercial/charter troll											
WPRFMC needs	7					4	4				4
Samoa needs	7		4			4	4				4
Degree of satisfaction	S					N	N				N
Small boat troll											
WPRFMC needs	7		4			4	4				4
Samoa needs	7		4			4	4				4
Degree of satisfaction	S		N			N	N				N

1/ Symbols:

Needs: See footnote 1, Table 4.

Satisfaction: See footnote 1, Table 6.

Table 33. WPRFMC and Samoa catch data needs and the degree to which current Samoa collection fulfills Council needs.^{1/}

Fishery	Catch Data								
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition	Size composition (by species)
<u>Billfish</u>									
Commercial/charter troll									
WPRFMC needs			$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$		$\frac{4}{2}$	4
Samoa needs			$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$		$\frac{4}{2}$	4
Degree of satisfaction			$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$		$\frac{4}{2}$	N
Small boat troll									
WPRFMC needs			$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$		$\frac{4}{2}$	
Samoa needs			$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$		$\frac{4}{2}$	
Degree of satisfaction			$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$		$\frac{4}{2}$	

^{1/} See footnote 1, Table 32

^{2/} Charter

^{3/} Commercial

RANKED DATA COLLECTION TECHNIQUES

A fish ticket system to gather Council-needed data on American Samoa troll fisheries is impractical.

Both log and survey systems to gather data on the small Pago Pago troll fleet are feasible; the log would require approximately .15 man-year's labor annually, the survey .25 man-years. Additionally, implementation of the log system would require approximately .05 man-years of OMR staff time to explain procedures.

The log system is ranked first, the survey approach second.

6.3.2.2. GUAM AQUATIC AND WILDLIFE RESOURCES DIVISION

Only the troll fishery operating out of Guam is of management concern to the Council - specifically, the catch and effort in that fishery associated with billfish. This fishery is prosecuted by small vessels - most under 30 feet - the bulk of which, because of the limited moorage on the Island, are launched each fishing trip from one of the three harbors or five principal launch sites. The precise number of vessels participating in the fishery is not known. However, the Aquatic and Wildlife Resources Division (AWRD) estimates that during the period July, 1977-June, 1978, an average of 20 off-shore fishing boat trips were made daily from all Island harbors and launch sites; about half of all offshore trips are thought to originate and conclude at Agana Boat Basin. AWRD data reveal that virtually all billfish catches by troll fishermen during 1977-1978 were made during the months of April, May and June.

While commercial and charter activities are an element in the Guam troll fishery, clearly most fishing is for recreational and subsistence purposes. This is especially true with regard to billfish, where recreational fishermen dominate. This, coupled with the lack of an organized or centralized fish market in Guam, results in few billfish reaching commercial channels.

Billfish catch/effort data are currently produced by the AWRD, the Guam Department of Public Safety and the United States Coast Guard. The system is based on a four-day-per-month survey by a Division biologist of Agana Boat Basin, where all fishing parties are interviewed either upon departure or return. Detailed catch and effort data are gathered through these interviews (an interview form is shown in Appendix 6.4). The other harbors or launch sites on the Island presently are not surveyed. Additionally, an aerial survey is accomplished two days each month during which the number of vessels by gear type is tabulated and fishing area noted (Appendix 6). Certain "effort description" data are yielded

by the Department of Public Safety vessel registration system and Coast Guard vessel documentation requirements.

Tables 34 and 35 indicate catch and effort data requirements of both the Council and the AWRD for the small boat troll fishery. Entries reflect the specific data items desired, their priority and the necessary periodicity of collection. Council requirements pertain only to billfish catch and effort in the troll fishery. AWRD needs relate to catch and effort associated with the fishery as a whole. The bulk of AWRD-needed data items are required on a monthly basis. Currently collection systems fulfill about 50 percent of Council requirements for nearly all items. "Effort description" needs of the Council are met by the combination of AWRD, Department of Public Safety and Coast Guard survey and vessel registration and documentation activities. The "2" entries in Tables 34 and 35 reflect that AWRD surveys presently cover only Agana Boat Basin. According to AWRD estimates, about half of offshore fishing trips - the bulk of which are accounted for by trollers - are made from Agana Boat Basin. While providing most required "effort description" data, the combined activities of AWRD, Department of Public Safety and the Coast Guard do not provide information on vessel and gear characteristics and fishermen profiles.

Approaches to upgrading the system are:

A LOGBOOK SYSTEM

A permanent logbook would be produced and distributed among the troll fishermen. The system would be voluntary unless a licensing system was authorized by the Legislature. Guam officials indicate that such action is feasible. The fishermen, through the major sports fishing organizations on Guam, have indicated they will cooperate in a voluntary system.

Logbooks would be designed and placed on each vessel by AWRD personnel or by AWRD through the fishermen's organizations. Both techniques are probably necessary since not all billfish fishermen are members of an Island fisherman organization, and the number of members relative to the total number of active billfish fishermen is unknown.

A voluntary logbook system is estimated to annually require one man-year's labor spent interacting with the fishermen and their organizations and in editing the data obtained.

SURVEY/INTERVIEW SYSTEM

An expanded survey system would mesh well with the existing offshore fishing survey. Basically, the same techniques and procedures now utilized should be expanded to cover those harbors and launch sites not presently surveyed. Survey coverage of Agana Boat Basin,

Fishery	Effort description <u>2/</u>	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets	Bait type	Bait quantity used .	No. gear sets
<u>Billfish</u>														
Small boat troll														
WPRFMC needs	7		4			4	4				4			
Guam AWR needs	7		2 4			4	4 4				4			
Degree of satisfaction	5		2			2	2 2				2			

1/ Symbols:
Needs: See footnote 1, Table 4.
Satisfaction: See footnote 1, Table 6.

Table 35. Western Pacific Regional Fishery Management Council and Guam catch data needs and the degree to which current Guam collection fulfills Council needs. 1/

Fishery	Catch Data								
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition	Size composition (by species)
<u>Billfish</u>									
Small boat troll									
WPRFMC needs			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	
Guam AWR needs			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	4
Degree of satisfaction			<u>2</u>		<u>2</u>	<u>2</u>		<u>2</u>	4

1/ See footnote 1, Table 34

the principal fishing harbor from which 40 percent of the offshore effort is estimated to originate, could remain at four days per month. The other seven major harbor/launch sites - accounting for nearly all the remaining effort - could be surveyed four days (sites and days chosen randomly) per month.

The enhanced survey alternative would involve primarily an increase in AWRD personnel time devoted to surveying and interviewing, and assumes a dependence on these methods as the principal source of the required data. About .8 man-year would be required annually, or twice the level currently required to survey Agana.

A FISH TICKET SYSTEM

Use of a fish ticket system to collect billfish data presents serious problems because:

1. Catches of billfish are small (estimated at less than 1,500 kg. during June, 1977-July, 1978) and are made in a three-month period.
2. Relatively little of these catches enter commercial channels because of the chiefly recreational orientation of the fishermen.
3. There is no centralized fish auction/market and sales are made by individual fishermen to numerous small retail outlets, restaurants and hotels.

For these reasons, a fish ticket system to collect billfish data in Guam is impractical.

COMBINED LOGBOOK AND SURVEY SYSTEM

A further alternative is a combination logbook survey method. In addition to the logbook system described previously, AWRD personnel would survey harbors and launch sites several times per month to check on the logbook system and to gather biological data. The present .4 man-year's annual effort would be continued to supplement the logbook efforts.

RANKED DATA COLLECTION TECHNIQUES

As discussed, a fish ticket system to gather data on Council-needed Guam fisheries is impractical.

Two alternative survey systems were developed: one continues and augments the current survey; the second, a reduced survey, complements a log system.

The system designed to augment the existing, well-run system by increasing survey coverage to presently unsurveyed segments of the fishery, is estimated to require the addition of .3 man-year's

labor annually over that currently expended, for a total of .7.

Qualitatively, an enhanced survey has the advantage of an existing, efficiently-run base. Additionally, this option requires little participation by fishermen or attendant AWRD public relations effort and no political action.

The second survey alternative is intended to supplement a log system; the annual labor requirement is estimated at .2 man-years.

Summarizing the costs, both quantitative and qualitative, of alternative Guam data collection schemes, the following results are yielded:

Alternative	Net* Cost Man-Years	Qualitative Consideration	Ranking
Enhanced survey	.3	No senior time, no political decision. Backup survey.	1
Log	.6	No backup survey.	3
Logbook with reduced survey	.8	Backup survey.	2

*Current activities replaced by these alternatives will yield approximately .4 man-years of biologist time assume applied to the alternatives.

In computing the net cost of implementing collection alternatives, the estimated .4 man-year's cost of the current survey system is assumed available for proposed alternatives.

The voluntary log/reduced survey combination is ranked above the voluntary log alone, since the value of a backup survey augmenting the log outweighs its slight additional cost.

6.3.2.3. HAWAII DIVISION OF FISH AND GAME

As shown in Tables 36 and 37, Hawaii-based fisheries exploiting billfish, precious coral, lobster and bottomfish, are of management concern to the Council. For the latter two species, however, only Northwest Hawaii stocks have been targeted for Council attention.

Several Hawaiian fisheries take billfish as a principal or incidental catch: longline ("ahi"), pole and line ("aku"), handline

Table 36. Western Pacific Regional Fishery Management Council and Hawaii effort data needs and the degree to which current Hawaii collection fulfills Council need. 1/

	Effort Data														
Fishery	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets	Bait type	Bait quantity used	No. gear sets	No. successful sets
Billfish															
Commercial/charter troll															
WPRFMC needs	7						<u>4</u>	<u>4</u>			<u>4</u>				
Hawaii DFG needs	7						<u>4</u>	<u>4</u>			<u>4</u>				
Degree of satisfaction	S						<u>S</u>	<u>S</u>			<u>N</u>				
Small boat troll															
WPRFMC needs	7		<u>4</u>				<u>4</u>	<u>4</u>			<u>4</u>				
Hawaii DFG needs	7		<u>4</u>				<u>4</u>	<u>4</u>			<u>4</u>				
Degree of satisfaction	S		<u>S</u>				<u>S</u>	<u>S</u>			<u>N</u>				
Tuna handline															
WPRFMC needs	7	<u>4</u>					<u>4</u>	<u>4</u>			<u>4</u>				
Hawaii DFG needs	7	<u>4</u>					<u>4</u>	<u>4</u>	4		<u>4</u>				
Degree of satisfaction	S	<u>S</u>					<u>5</u>	<u>N</u>	N	N	<u>N</u>				
Tuna longline															
WPRFMC needs	7						<u>4</u>	<u>4</u>			<u>4</u>				
Hawaii DFG needs	7						<u>1</u>	<u>1</u>	1		<u>1</u>	1	1		
Degree of satisfaction	S						<u>N</u>	<u>N</u>			<u>S</u>				
Tuna pole and line															
WPRFMC needs	7						<u>4</u>	<u>4</u>			<u>4</u>				
Hawaii DFG needs	7					4	<u>4</u>	<u>4</u>			<u>4</u>	4	4		
Degree of satisfaction	S					N	<u>5</u>	<u>N</u>			<u>5</u>	5	5		
Bottomfish															
NW Hawaiian handline															
WPRFMC needs	7						<u>4</u>	<u>4</u>			<u>4</u>				
Hawaii DFG needs	7		<u>4</u>				<u>4</u>	<u>4</u>		4	<u>4</u>				
Degree of satisfaction	S		<u>N</u>				<u>S</u>	<u>N</u>			<u>S</u>				
NW Hawaiian trap															
WPRFMC needs	7						<u>4</u>	<u>4</u>			<u>4</u>				
Hawaii DFG needs	7						<u>4</u>	<u>4</u>		4	<u>4</u>				
Degree of satisfaction	S						<u>S</u>	<u>N</u>			<u>S</u>				

Table 36 (Cont.)

Fishery	Effort Data										
	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets
											Bait type
											Bait quantity used
											No. gear sets
											No. successful sets
NW Hawaiian lobster											
WPRFMC needs	7					4	4			4	
Hawaii DFG needs	7					4	4		4	4	4
Degree of satisfaction	S					S	N			S	
Precious coral											
WPRFMC needs	7	4				4	4				
Hawaii DFG needs	7	4				4	4				
Degree of satisfaction	5	5				5	5				

1/ Symbols

Needs: See footnote 1, Table 4.

Satisfaction: See footnote 1, Table 6.

Table 37. Western Pacific Regional Fishery Management Council and Hawaii catch data needs and the degree to which current Hawaii collection fulfills Council needs. 1/

Fishery	Catch Data									
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition	Size composition (by species)	Sex composition (by species)
Billfish										
Commercial/charter troll										
WPRFMC needs			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	4	
Hawaii DFG needs				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	4	4
Degree of satisfaction			<u>S</u>		<u>S</u>	<u>S</u>		<u>S</u>	N	
Small boat troll										
WPRFMC needs			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>		
Hawaii DFG needs			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>		
Degree of satisfaction			<u>S</u>		<u>S</u>	<u>S</u>		<u>S</u>		
Tuna handline										
WPRFMC needs			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	4	
Hawaii DFG needs			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	4	4
Degree of satisfaction					<u>4</u>	<u>4</u>		<u>4</u>	N	
Tuna longline										
WPRFMC needs			<u>4</u>		<u>4</u>	<u>4</u>		<u>4</u>	4	
Hawaii DFG needs			<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>	1	<u>1</u>	4	4
Degree of satisfaction			<u>S</u>		<u>4</u>	<u>4</u>		<u>4</u>	N	
Tuna pole and line										
WPRFMC needs				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>		
Hawaii DFG needs	4	4		<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	4	
Degree of satisfaction				<u>5</u>	<u>4</u>	<u>5</u>		<u>5</u>		
Bottomfish										
NW Hawaiian handline										
WPRFMC needs				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>		
Hawaii DFG needs			<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>		
Degree of satisfaction			<u>N</u>	<u>3</u>	<u>3</u>	<u>3</u>		<u>3</u>		
NW Hawaiian trap										
WPRFMC needs				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>		
Hawaii DFG needs				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>		
Degree of satisfaction				<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>		

Table 37 (Cont.)

Fishery	Catch Data								
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition	Size composition (by species)
NW Hawaiian lobster									
WPRFMC needs			$\frac{4}{4}$	$\frac{4}{4}$	$\frac{4}{4}$	$\frac{4}{4}$		$\frac{4}{4}$	$\frac{4}{4}$
Hawaii DFG needs			$\frac{4}{4}$	$\frac{4}{4}$	$\frac{4}{4}$	$\frac{4}{4}$		$\frac{4}{4}$	$\frac{4}{4}$
Degree of satisfaction			$\frac{10}{10}$	$\frac{4}{4}$	$\frac{4}{4}$	$\frac{4}{4}$		$\frac{4}{4}$	$\frac{10}{10}$
Precious coral									
WPRFMC needs				$\frac{4}{4}$	$\frac{4}{4}$	$\frac{4}{4}$		$\frac{4}{4}$	
Hawaii DFG needs				$\frac{4}{4}$	$\frac{4}{4}$	$\frac{4}{4}$		$\frac{4}{4}$	
Degree of satisfaction				$\frac{5}{5}$	$\frac{5}{5}$	$\frac{5}{5}$		$\frac{5}{5}$	

1/ See footnote 1, Table 36

and troll fisheries. About 18 longliners operate out of Hawaii, approximately 14 vessels based at Kewalo Basin and Honolulu Harbor on Oahu, and about 4 at Napoopoo and Kawaihae on the island of Hawaii. These vessels fish primarily for tunas, but catch billfish, wahoo and mahimahi incidentally. The bulk of incidental catches are marketed through the Honolulu auction market, and secondarily the Hilo auction.

The pole and line fishery is included under "billfish" because of the incidental take of wahoo and mahimahi by the 14-15 vessels comprising this fishery. About 12 vessels fish out of Kewalo Basin, 2 are based on Maui (Kahului or Maalaea) and 1 on the Island of Hawaii (at Kawaihae). The bulk of incidental wahoo and mahimahi catches are marketed through the Honolulu auction, but small volumes reach the fresh fish markets on Maui and Hawaii.

The handline fishery exploits primarily tunas, but incidentally catches billfish. Over 40 small vessels prosecute this fishery, nearly all fishing out of ports and ramps on the Island of Hawaii. Most production is marketed through the Hilo auction.

Troll gear accounts for a substantial volume of Hawaii landings of billfish, wahoo and mahimahi. This fishery is conveniently divided into two segments: (1) the larger vessels - dominated by sports charter and commercial interest; and (2) smaller boats (the "mosquito fleet") dominated by recreational/subsistence elements. There are about 70 larger vessels, based primarily at Kewalo Basin and the Kona Coast (Hawaii), but also on Maui (Maalaea, Lahaina) and a few other harbors. The precise number of small trollers is unknown, but over 10,000 land-stored vessels - many no doubt utilized at least occasionally for trolling - were registered in the State in 1976. Small volumes of the trollers' outputs are marketed through auction markets, but the bulk is thought to go to small retail outlets, independent fish dealers or is retained by recreational and subsistence fishermen.

One commercial operator, utilizing a submersible, fishes out of Oahu for pink and gold coral. However, numerous small operators using diving techniques fish commercially and recreationally for black coral. Most catches are sold directly to jewelry manufacturers.

Northwestern Hawaiian Island lobster is currently trapped by a handful of vessels fishing out of Honolulu. Nearly all catches are marketed through the Honolulu auction market and several Oahu independent retailers.

Northwestern Hawaiian Island bottomfish is exploited by three to four vessels fishing out of Honolulu. Both handlines and traps are utilized. Vessels fishing the area sometimes fish for both lobster and bottomfish. Bottomfish catches are marketed through the Honolulu auction and independent dealers.

Slightly different techniques are presently utilized to collect descriptive data on each of the fisheries described above. With one exception, however, report forms submitted monthly to HF&G by fishermen on commercial¹/ activity account for all data gathered on these fisheries; an observer program administered by NMFS produces additional information on NWHI lobster and bottomfish operations.

Specialized pole and line and longline fishery logbook forms are submitted monthly to HF&G by fishermen (or their agents). These forms (shown in Appendix 6.4) have been developed over a number of years and yield a considerable amount of catch and effort data.

In all the other fisheries except the one large-scale precious coral operation, commercial fishermen are required to submit a monthly Fish Catch Report form detailing catch, economic and limited effort information. An example of this form is provided in Appendix 6.4.

Recreational troll and precious coral fisherman are not required to report their activities. The NMFS observer produces detailed data - concentrated on effort and biological - on selected NWHI lobster and bottomfish operations; samples of report forms utilized are shown in Appendix 6.4.

The one large-scale precious coral fishing operation is required to submit monthly to both HF&G and NMFS data on species harvested, wet weight, area nad depth of harvest, date of harvest and fishing time. These data must be documented in daily logbooks.

Certain "effort description" information on the above fisheries is yielded by the Hawaii Department of Transportation and Coast Guard vessel registration and documentation requirements. Samples of these forms are shown in Appendix 6.4.

As indicated in Table 37, Council requirements for catch data on the Hawaiian-based fisheries of concern are largely satisfied by current data collection activities of HF&G. Exceptions are the troll fisheries taking billfish, where sizeable non-commercial catches are not reported. Additionally, commercial catches in these fisheries are believed to be under-reported. Council required catch size composition data in selected fisheries either are not collected (billfish) or collected to an inadequate degree (lobster).

1/ Only data on commercial - i.e. when product is sold - catches are required; recreational/subsistence activities need not be reported.

Present HF&G effort data collection satisfies Council needs only for the submersible precious coral fishery (Table 36). For other fisheries of Council concern, many data items are either not currently collected, or current collection only partially fulfills Council needs.

Approaches to upgrading the system are complex because of the number of fisheries involved (nine) and the fact that different data collection problems are presented by the different fisheries, depending on the collection method addressed. To avoid repetition, rather than exploring fishery-by-fishery each of the collection alternatives, a slightly different approach is taken.

A LOGBOOK SYSTEM

The pole and line fishery is of concern to the Council because of the small incidental catches of mahimahi and wahoo. These species are of secondary importance to the Council and the current quasi-logbook system provides sufficient information for Council needs. No further efforts are deemed to be justified.

The longline fishery lends itself to extensive data collection through an improved logbook system based on the presently required logbook-type monthly report. Information requested by the current forms could be expanded and modified to meet Council needs. To minimize time required for log completion - an important factor in Hawaii - it is recommended logs take the form of simple multi-copy forms, to be completed by fishermen at the end of each fishing trip. Logbook completion and submission would continue as part of the licensing procedure. Log forms could be issued to fishermen yearly with the licenses. Submission of one copy of each of the completed forms would be by mail and through the longline fishermen's organization with some personal follow-up by a HF&G representative. A copy could be retained by the fisherman or the fisherman's organization for their records. The system would require .20 man-years annually for fishermen contact to insure data quality.

A logbook system for the Northwestern Hawaii lobster (trap) and bottomfish (trap and handline) fisheries would follow the pattern suggested for the longline fishery. The major difference is that reporting requirements and procedures would be based on the techniques presently utilized in this fishery - the Fish Catch Report - not those in the longline fishery. Approximately .10 man-years per year of HF&G personnel time would be required to keep the system running smoothly, producing the desired information.

Logbook techniques are difficult to apply to the tuna handline fishery due to the large number of vessels, their small size, and the short duration of trips (less than 24 hours). The system could be employed, however, along the same lines as utilized in the longline, lobster and bottomfish fisheries (see above). Different log collection methods would have to be utilized because of the small

size and dispersion of tuna handliners. In order to collect completed logs, an HF&G technician would have to circulate regularly among fishermen at the Hilo auction, other marketing points and at the ports on Hawaii. It is estimated that about .5 man-years per year would be required for this activity.

A logbook system for the large- and small-scale troll fisheries would be voluntary because of the important and sizeable recreational element in these fisheries.

It is recommended that the steps outlined in NMFS' "Proposal for a Logbook Pilot Study" (Appendix 6.5) be utilized. This approach will require about 2.15 man-years of personnel time over an eight-month period. This study would determine the response of recreational fishermen to a voluntary logbook system, the sample size necessary for adequate coverage and the personnel time required for implementation and maintenance of an ongoing system. If results were encouraging, steps could be taken to actually implement a full-scale system. The present logbook and reporting requirements in the single large-scale coral fishery fully satisfies Council data needs in this fishery; alternative approaches to collecting data on this operator will not be discussed. The precious coral divers could be incorporated in the pilot logbook system for the troll fisheries at almost no additional cost (Appendix 6.5).

SURVEY/INTERVIEW SYSTEM

The longline fishery data can be obtained using survey/interview methods. However, because of the small number of boats, their longer trips and irregular trip schedules, the surveyor would have to keep in close contact with the fishermen and their representative in the longliner's organization. The surveyor would then be alerted to visit the vessels as they were reported in port. Approximately .35 man-years per year would be required to collect the necessary data through interviewing of fishermen.

The large number of vessels in the troll fisheries and the scores of landing/launching sites, preclude the use of interview/survey techniques on a continuing basis. A sample interview system could be undertaken but in our opinion, the only practical method of obtaining the appropriate information is via a logbook system as described previously.

For the numerous divers harvesting black coral for both commercial and recreational purposes, a survey approach to gathering the necessary information faces prohibitive costs for the same reasons outlined for the troll fisheries above.

A FISH TICKET SYSTEM

If initiated, a fish ticket system should cover all species entering commercial channels. A system designed to collect data on just billfish, mahimahi, wahoo, lobster and precious coral, would be impractical. The system, if initiated, should cover all buyers and all species entering commercial channels. Such a system would logically replace the present Fish Dealer's Report System. It would take one man-year initially to establish the identity and addresses of all buyers, to explain the system and distribute the ticket forms.

After introduction, 1.5-2.0 man-years per year would be required to follow-up system introduction and keep it operating smoothly. However, if the fish ticket system supplants the present Fish Dealer's Report System, Enforcement Division personnel time now devoted to supporting this system could be shifted to support of the new system and would not represent any increase in Enforcement Division personnel time. Equipment (essentially one automobile on each of the islands of Oahu, Hawaii, Maui and Kauai) could also be transferred to support the new system.

The fish ticket approach is not practical for the Hawaiian troll fisheries as a major portion of catches do not enter commercial channels.

RANKED DATA COLLECTION TECHNIQUES

The current quasi-fish ticket system used to enforce licensing requirements could be modified slightly to collect improved catch and some effort data. Essentially, this is a no-cost operation, since most of the appropriate markets are already covered and the principal changes would be to modify the collection forms.

Log and survey collection alternatives are assessed for each fishery in turn.

Based on the discussion of Section 3 data on the pole and line fishery, catch and effort directed at Council species is adequately covered and no alternatives are proposed.

Logbook coverage of the longline fleet is estimated to cost .2 man-year's labor annually; survey coverage .35 man-years.

Northwestern Hawaii lobster and bottomfish fisheries could be covered by a log system at a cost of .1 man-year's time or by survey at a cost of .2 man-years annually.

Tuna handline fishery data collection could be accomplished by log (.5 man-year's time) or survey (.4 man-years annually).

As noted in Section 3, NMFS proposed feasibility study of coverage of the troll fishery by a voluntary log system is recommended. Data collection of this extensive fishery by survey/interview would be prohibitively expensive.

The above information is summarized in the following table contrasting costs for data collection alternatives:

Fishery	Log			Survey		
	Cost	Qualitative Assessment	Rank	Cost	Qualitative Assessment	Rank
Longline	.20	None	1	.35	None	2
NW bottomfish and lobster	.10	None	1	.20	None	2
Pole and line	Current log adequate					
Troll	Currently planned voluntary log is only feasible alternative					
Tuna handline	.50	None	2	.40	None	1

6.3.2.4. NORTHERN MARIANAS FISHING AUTHORITY

Only the troll fishery operating out of the Northern Marianas is of concern to the Council. This fishery produces only an occasional billfish (number unknown) and is prosecuted almost exclusively from small outboard-powered boats.

In 1977, only 97 vessels were registered (only powered vessels are required to be registered) in the Islands, 78 of them on Saipan. A total of 103 fisherhmen were members of the fishermen's cooperative in that year, 58 on Saipan. Offshore fishermen (those with powered vessels) most commonly use troll gear. All but a handful of the fishing vessels in the Northern Marianas are trailered and launched from one of about five ramps on Saipan and one or two ramps on each of Rota and Tinian Islands. A small harbor exists on both Saipan and Tinian Islands.

While part-time commercial operators are present in the fishery, the bulk of offshore fishing is done for recreational and subsistence purposes. This fact, combined with the small catches and the still developing marketing system in the Islands, results in very few billfish reaching normal commercial channels.

Limited data on billfish catches are obtained through fishermen's fish catch reports to the fishermen's cooperative and by a periodic survey of principal retail outlets by the Fishing Authority. These activities yield an estimate of monthly fish catch with species breakdown for only a few species and no effort information except that obtained through vessel registration.

Tables 38 and 39 indicate catch and effort data requirements for both Council and Fishing Authority with respect to the small boat troll fishery. Entries reflect specific data items desired, their priority, and necessary periodicity of collection. Council requirements pertain only to billfish catch and effort in the troll fishery. Fishing Authority needs relate to catch and effort associated with the fishery as a whole. Table entries indicate other contrasts in Council and Fishing Authority data needs. However, the difference in periodicity requirements (monthly for the Council versus quarterly for the Fishing Authority) is the only one likely to generate conflicts in agency data collection requirements.

The only effort information now available is limited "effort describition" data yielded by boat registration requirements of the Saipan Port District (Appendix 6.4). These data are not sufficient to fulfill either Council or Fishing Authority needs. Some of the Council's catch information requirements are satisfied by current Fishing Authority data collection activities, as indicated on Table 39. While not yielding numbers of billfish caught or area of catch, current data collection activities do provide an estimate of the weight of monthly billfish catches. These estimates, however, are suspect due to the data collection problems resulting from personnel limitations.

Approaches to upgrading the system are:

A LOGBOOK SYSTEM

Data collection utilizing logbook methods would have to be voluntary; licensing or enforced reporting requirements are not thought to be feasible. About 40 percent of all fishing vessels registered in the Islands belong to fishermen's cooperative members. Co-op members are the most active and productive fishermen. The manager of the Fishing Authority is also manager of the co-op. Thus, logbook distribution and collection could utilize co-op facilities and communication channels. Log submission could be limited to fishermen landing billfish, or extended to all co-op offshore fishermen.

To operate effectively, a cooperative-based logbook system, each of the three cooperative locations (Saipan, Rota and Tinian), would have to be visited weekly to distribute logbooks, explain the system, collect statistical and biological data and monitor the operation. It is estimated that .5 man-years would be required.

Table 38. Western Pacific Regional Fishery Management Council and Northern Marianas effort data needs and the degree to which current Northern Marianas collection fulfills Council needs.^{1/}

Fishery	Effort Data														
	Effort description <u>2/</u>	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished(dragged,pond)	Depth gear set	No.hooks/traps/lines/nets	Bait type	Bait quantity used	No. gear sets	No. successful sets
Small boat troll ^{2/}															
WPRFMC needs		7		4			4	4			4				
N. Marianas needs		7		5			5	5			5				
Degree of satisfaction		5		N			N	N			N				

^{1/} Symbols
 Needs: See footnote 1, Table 4.
 Satisfaction: See footnote 1, Table 6.

^{2/} Included in N. Marianas category "small scale offshore" fishery.

Table 39. Western Pacific Regional Fishery Management Council and Northern Marianas catch data needs and the degree to which current Northern Marianas collection fulfills Council needs.^{1/}

Fishery	Catch Data							
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition
Small boat troll								
WPRFMC needs			4		4	4		4
N. Marianas needs			5		5	5		5
Degree of satisfaction			5		5	5		5

^{1/} See footnote 1, Table 38

SURVEY INTERVIEW SYSTEM

To sample all offshore fishermen, the five principal harbor/launch sites on the three major islands- Saipan (three), Rota (one) and Tinian (one) would have to be surveyed periodically. At the present level of offshore fishing activity, this approach would produce little data for the effort. Concentration of survey efforts on cooperative members would be more cost effective. Initially, all (or a sample of) powered fishing boats (names obtained from vessel registration records) could be interviewed to establish the proportion of total billfish catch and effort accounted for by cooperative members. Concomitantly, the bulk of additional "effort description" data required could be gathered. These data could then be utilized to adjust data gathered in co-op surveys to obtain estimates of total billfish catch and effort. The system would require about .8 man-years annually to cover the three cooperative locations.

A FISH TICKET SYSTEM

A fish ticket system is not a feasible option, as much of the catch by the troll fleet does not enter commercial channels.

RANKED DATA COLLECTION TECHNIQUES

As detailed, a fish ticket system to collect Council-needed Northern Marianas fishery data is not appropriate; feasible options are logbook and survey/interview systems.

Quantitatively, the cooperative-based log system is estimated to annually require .5 man-years of labor, the co-op survey option .8 man-years.

Qualitatively, both options are similar in that an estimated 40 percent of fleet effort is covered. Additionally, the survey system samples only a part of the co-op effort, whereas a log system theoretically covers all of this effort.

Based on the above, a voluntary cooperative-based log system is ranked first, a survey system second.

6.3.2.5. NATIONAL MARINE FISHERIES SERVICE

Collection of data describing domestic operations is the responsibility of the State, Commonwealth or Territorial fisheries agencies within whose jurisdiction those operations are prosecuted. Foreign fisheries, on the other hand, fall under the purview of the NMFS. In the context of this report, foreign fishing activities can be grouped in two categories; those taking place within the FCZ, and those prosecuted outside the FCZ. The council is only mandated to collect data on foreign operations in the former category, but stock analyses require catch/effort data on all removals from

exploited fish stocks. While this presents practical difficulties to the Council, especially for highly migratory species such as billfish, this section of necessity, deals primarily with information collection alternatives for foreign fishing operations under the purview of the Council.

Under NMFS responsibility, only the foreign tuna longline fisheries incidentally taking billfish, the foreign bottomfish fisheries and the foreign precious coral fishery are of concern to the Council. Of these fisheries, operational aspects are known in detail only for the tuna longline fishery based in American Samoa.

The longline vessels based at Pago Pago, American Samoa, fish primarily for albacore, bigeye and yellowfin tuna in areas beyond the FCZ. Billfish, wahoo and occasionally mahimahi are taken incidentally in the zone. The number of vessels usually fluctuates between 100 and 150, but has reached as high as 280 in the past. Extended trips are common and vessels may return to Pago Pago only once or twice yearly. Nearly all fishing is done well beyond 200 miles from American Samoa, but some effort does take place within American Samoa's 200-mile FCZ. Catches are delivered almost exclusively to the two canneries on American Samoa.

Foreign-based Japanese, and occasionally Taiwanese and South Korean, longliners prosecute a seasonal tuna fishery north of Hawaii that at times enters FCZ waters off the Islands. The number of vessels varies from season to season. Most never visit island ports. Some longlining occurs off Guam and the Northern Marianas, but little is known of this activity except that it is sporadic and relatively small scale. These boats also seldom visit island ports.

Similarly, little is known of the foreign bottomfish and precious coral fisheries that are sporadically prosecuted in FCZ waters off Hawaii, and occasionally Guam and the Northern Marianas. Only a few trawlers and line boats are involved.

NMFS data collection activities in these fisheries are limited to the longline fishery based in American Samoa. Detailed catch and effort data are provided by logbooks completed by vessel captains, and by reports obtained with cannery cooperation. A joint effort by NMFS and the Office of Marine Resources, American Samoa, produce these data which are mailed in raw form to NMFS in Honolulu for processing and evaluation.

NMFS does gather data on other longlining operations within the FCZ (and outside as well), but these are primarily culled from Japanese Government fisheries publications after considerable time lag. Little data are presently available describing foreign bottomfish and precious coral operations.

Tables 40 and 41 indicate catch/effort data requirements of both the Council and NMFS with respect to these fisheries; entries reflect specific data items desired, their priority and necessary periodicity of collection. Council requirements pertain only to catch and effort in the appropriate fisheries within the FCZ. Further, in the tuna longline fisheries, only catch/effort data associated with billfish are required. NMFS needs relate to catch and effort associated with the noted fisheries as a whole. Table entries indicate that data periodicity requirements of both the Council and NMFS are comparable, but that NMFS needs are slightly more extensive.

The degree to which current data collection activities by NMFS satisfy Council requirements is reflected in the table entries. The "4" entries under tuna longline data items reflect that currently collected information on the Samoa-based fishery, by far the most important longlining operation under the purview of the Council, satisfies nearly all Council data requirements. Information describing other longlining activities are inadequate, however, due to the long lag time before they become available. Data describing billfish catch and effort associated with the limited longlining operations off Guam and the Northern Marianas lack sufficient detail for Council needs.

Data describing foreign bottomfish and precious coral operations are presently sparse and inadequate for Council needs. Approaches to upgrading the data collection to meet Council needs are:

A LOGBOOK SYSTEM

Detailed catch (including that of billfish) and effort information produced by the present logbook system, complements data gathered through the canneries and essentially fulfills Council data needs in this fishery. The logs are collected by the full-time OMR technician, who also measures a sample of albacore from each unloading. Fish measurement sampling could be extended to billfish with the devotion of an additional .2 man-years of the technician's time yearly.

Foreign longline operations not based in American Samoa present a difficult problem. The same logbook format could be utilized and information required for billfish activities with the FCZ. It is unlikely that foreign governments will permit their vessels to supply directly to NMFS information on activities outside the FCZ and this will have to be obtained, in summary form, through government-to-government channels.

Foreign operators wishing to fish for bottomfish and precious coral within the FCZ require permits from the United States Government. The permits could require submission of catch and effort data in logbook format. No additional manpower would be required to integrate the data into the system.

Table 40. Western Pacific Regional Fishery Management Council and National Marine Fisheries Service - Honolulu effort data needs and the degree to which current NMFS-Honolulu collection fulfills Council need.^{1/}

Fishery	Effort Data										
	Effort description	No. fishermen (anglers)	No. vessel-trips	No. angler-trips	Days/hours absent	Days/hours searching	Days/hours fishing	Statistical area	Area fished (dragged, pond)	Depth gear set	No. hooks/traps/lines/nets
Bait type											
Bait quantity used											
No. gear sets											
No. successful sets											
Billfish											
Foreign tuna longline											
Priority WPRFMC needs	7					4	4			4	
NMFS needs	7					4	4		4	4	
Degree of satisfaction	4					4	4			4	
Bottomfish											
Foreign line fishery											
Priority WPRFMC needs	7					4	4			4	
NMFS needs	7					4	4			4	
Degree of satisfaction	N					N	N			N	
Foreign trawl fishery											
Priority WPRFMC needs	7					4	4	4			
NMFS needs	7					4	4	4	4		
Degree of satisfaction	N					N	N	N	N		
Precious coral											
Foreign trawl fishery											
Priority WPRFMC needs	7					4	4	4			
NMFS needs	7					4	4	4			
Degree of satisfaction	N					N	N	N			

^{1/} Symbols:
 Needs: See footnote 1, Table 4.
 Satisfaction: See footnote 1, Table 6.

Table 41. Western Pacific Regional Fishery Management Council and NMFS-Honolulu catch data needs and the degree to which current NMFS-Honolulu collection fulfills Council needs. 1/

Fishery	Catch Data							
	No. schools sighted	No. schools fished	No. fish caught/landed	Wt. fish caught/landed	Statistical area of catch	Date/time of catch	Depth of catch	Species composition Size composition (by species) Sex composition (by species)
Billfish								
Foreign tuna longline								
WPRFMC needs			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	4
NMFS needs			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	4
Degree of satisfaction			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	S
Bottomfish								
Foreign line								
WPRFMC needs			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
NMFS needs			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Degree of satisfaction			<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>	
Foreign trawl								
WPRFMC needs			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
NMFS needs			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Degree of satisfaction			<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>	
Precious coral								
Foreign fishery								
WPRFMC needs			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
NMFS needs			<u>4</u>	<u>4</u>	<u>4</u>		<u>4</u>	
Degree of satisfaction			<u>N</u>	<u>N</u>	<u>N</u>		<u>N</u>	

1/ See footnote 1, Table 40

SURVEY/INTERVIEW SYSTEM

This approach is not feasible for any of those foreign fisheries not based in American Samoa, as the vessels involved seldom visit American ports.

In American Samoa, survey techniques could yield the required information on the foreign longline fishery, but this alternative is not explored as the present well-developed system efficiently produces almost all information required by the Council.

A FISH TICKET SYSTEM

A modified fish ticket is currently utilized in American Samoa to gather catch and selected biological data on foreign longline operations based there. This is part of an excellent data collection system developed by NMFS after considerable study. Present fish ticket procedures should be retained.

A fish ticket system is not feasible for data collection purposes in the other foreign fisheries of concern to the Council, as the catches in these fisheries are not marketed in the United States.

RANKED DATA COLLECTION TECHNIQUES

The above discussion narrows feasible collection alternatives for NMFS-collected data to one - a logbook system, covering foreign longline, bottomfish and coral fisheries. It is estimated that such a collection system could be implemented with existing NMFS Honolulu Laboratory capabilities. However, an unknown amount of high level NMFS, Washington, D.C. personnel time, as well as possible Department of State personnel time may be required.

6.3.3. DATA REDUCTION - BY AGENCY

6.3.3.1. AMERICAN SAMOA OFFICE OF MARINE RESOURCES

The Samoan Office of Marine Resources is not currently using data processing support in either data collection or analysis. However, government computer facilities are available. The system is used for storing and retrieving and listing data in various forms for government payroll, labor distribution, and equipment list reports for use by government departments.

A first alternative for reducing Samoan troll billfish catch/effort data is for the Office of Marine Resources to have the work done at the government computer center. Data entry could be handled using key punch equipment; verification of OMR personnel using printed lists and the original forms. Validation depends upon the availability of scientific programming.

Local reduction would require approximately .1 man-years of labor to the OMR, as well as .1 machine-years of data entry/editing equipment (key punch, CRT, etc.). Verification and validation may require the addition of scientific programming, as well as analytic expertise. Timeliness of updating the central data base with local data reduction depends on the accessibility of data processing capability in American Samoa.

Alternately, reduction of the data could be accomplished at a central site. Assuming equipment availability, the central reduction option would require about .1 man-years of labor and .1 machine-years of data entry/editing equipment. Verification and validation quality, as well as timeliness of central file updating would be entirely under Council control.

Quantitatively, costs of both local and central reduction of Council-needed American Samoa catch/effort data are identical - both options are estimated to require .1 man-years of data technician labor and .1 machine-years of data entry/editing equipment (key punch or key-to-disk or-tape).

Qualitatively, the ability of the Samoan Office of Marine Resources to reduce collected data is unclear. As noted, the Office is not currently using data processing equipment for either data storage or analysis. The Office is unlikely to inaugurate such use solely to satisfy Council data needs, particularly since the expected volume of needed data is low. Additionally, since data processing is not currently used, verification and especially validation procedures are probably not familiar to OMR personnel.

On the basis of the quantitative assessment modified by qualitative considerations, central Council reduction of Council-needed Samoa data is ranked first; local reduction second.

6.3.3.2. GUAM AQUATIC AND WILDLIFE RESOURCES DIVISION

The Guam troll fishery will generate only a modest amount of data needed for Council activities. The Government of Guam has an IBM 371/15-based computer system with tape and disk storage. Aquatic and Wildlife Service fishery data is scheduled to be processed by computer in 1979. The director of the computer facility has expressed a willingness to undertake data processing for the Council activities. Thus, locally reduced data can be provided to the Council with no additions to current data processing capacity. Further, there is expertise available to assure quality verification and validation. The degree of timeliness of central data file updating cannot be anticipated.

A second alternative is central site reduction of Guam data. This option would require the addition of .5 man-year's labor and .5 machine years of data entry/editing equipment. Verification and

validation quality and timeliness of central file updating is under Council control.

Quantitatively, local reduction of Council-needed Guam fishery data has zero cost. As noted, available Guam Government computer center capabilities are more than adequate. Additionally, the reduction of this data is already planned by the Aquatic and Wildlife Service and copies of reduced data could be easily provided to the Council data center. Central reduction is estimated to require .5 man-year's labor and .5 machine-year's time.

Qualitatively, both local and central reduction are capable of producing reduced data of an acceptable quality; both are consistent with current activities (this assumes facilities for central reduction). Timeliness of central file updating with local reduction is unknown, however, estimated to be good.

Based on the above, local reduction of Council-needed Guam fishery data is ranked first; central reduction second.

6.3.3.3. HAWAII DIVISION OF FISH AND GAME

Current Hawaii Division of Fish and Game data reduction activities are difficult to assess due to problems in the quality of collected data. For some fisheries, individual vessel monthly report forms are received between one and four months late. The HF&G files are closed arbitrarily after a period of time and coverage is not known. In addition to the usual problem of incomplete forms, HF&G personnel suspect that many forms are not completed accurately. Many Hawaiian fishermen have an inadequate command of English and either misinterpret report form instructions or make undecipherable entries. Superimposed on the problems is the reluctance, as expressed by many knowledgeable persons, of Hawaiian fishermen to report details of their fishing activities.

Current Hawaii Fish and Game data reduction procedures pose additional problems. Basic collection forms are organized such that data must be transcribed to coding forms before entry. Tabulated data is entered by key punching cards. Verification is by listing and checking.

Access to the State computer, an IBM 370/05, used by all State agencies, is a further problem. Job entry is by card deck at the computer, although HF&G has requested remote job entry equipment. Scheduling difficulties result in long turn-around time, an impediment to efficient data reduction. At the time of the LMR interview, system user needs were being assessed in an attempt to improve service and this may reduce turn-around time. Specific capabilities include producing data files on card decks or tape.

Local reduction can produce entered and verified data files in an appropriate form. Personnel limitations, however, suggest that timeliness of central file updating may be less than needed. As a first approximation, the volume of data generated can be expected to require about one man-year of labor and one machine-year of entry/editing equipment annually.

Central reduction would require .75 man-year's labor, .75 machine-years of entry/editing equipment. Validation quality and timeliness of central file updating would be centrally controlled.

Quantitatively, costs of local reduction of Council-needed Hawaii fisheries data are one man-year labor and one machine-year time for local reduction; for central reduction, .75 man-years and .75 machine-years.

Qualitatively, several features of Hawaii Department of Fish and Game's data processing capabilities raise doubts as to the Department's ability to meet Council needs. As discussed above, use of the State computer is difficult, all HF&G job entry being done by card deck. Additionally, deficient job scheduling results in possibly serious time delays - partially reflected in the increased data reduction cost estimates. HF&G personnel hiring restrictions suggest that serious backlogs may occur and that local Hawaii reduction may not allow timely updating of central Council files.

The above evidence suggests that central Council reduction of Council-needed Hawaii fisheries data be ranked first; local reduction second.

6.3.3.4. NORTHERN MARIANAS FISHING AUTHORITY

The Director of the Economic Development Division, administratively over the Fishing Authority, has expressed willingness to provide the Council with reduced fishery data on magnetic tape. However, data processing capability available to the Fishing Authority depends upon the Trust Territory Government's automatic Data Processing Unit continuing to be located in Saipan. The Trust Territory Government, along with its ADP facilities, may be relocated, probably within two years.

The Trust Territory's IMB 370/135 based system has sufficient key punch, card reader and disk storage facilities available. The system can provide either card or tape-based data files. The system is not fully utilized and the manager is seeking new business.

Should the Trust Territory computer system be removed from Saipan, the Economic Development Division plans to replace the system with a facility of its own, to handle all data processing and reporting for Northern Marianas agencies.

Based on our interview information, quality local data reduction can be accomplished at an estimated annual cost of .25 man-year's labor and .25 machine-year's time. As with all local options, timeliness of central file updating is unknown.

A second alternative, central Council reduction of Northern Marianas data, can be expected to require capabilities similar to those required for central processing of Samoa data - the addition of .25 man-year of labor and .25 machine-year of data entry/editing equipment. Reduction quality and central file updating timeliness are Council controlled.

Both local and central reduction will require an additional .25 man-year's labor and .25 machine-year's of entry equipment. The principal extenuating circumstance is the unknown replacement for the Trust Territory computer system due to be removed from Saipan, possibly by January, 1981. Northern Marianas Government officials assured the interviewer that the replacement was being contemplated; since capabilities of the new system are not known, a reasonable assumption is that capabilities will be adequate.

Central reduction of Council-needed Northern Marianas data is ranked first; local reduction second.

6.3.3.5 NATIONAL MARINE FISHERIES SERVICE

The Southwest Fisheries Center data processing philosophy separates routine local computing from central file maintenance, computing and reporting on common data needed by all Center division (Honolulu is a division). Central system capability is currently provided by a three-year contract (due to expire October, 1980), between NMFS and Computer Science Corporation with its INFONET computer system located in Los Angeles. Center data management personnel are currently reviewing alternative facilities to satisfy long-term Center needs. A report is expected in October, 1979.

Honolulu Laboratory ADP capability is provided by the University of Hawaii. The ADP unit is staffed by a supervisor, programmer and a key punch operator. Equipment includes two key punches, a remote CRT terminal and a remote 300/1200 BAUD keyboard printer terminal.

The INFONET System is capable of providing all data management services to the Honolulu Laboratory. Access is via a multiplexer reached at a local telephone number. Data entry is by either card deck or magnetic disk or tape. Card decks can be entered directly at the Coast Guard's remote job entry terminal located at the Honolulu Federal Building.

Tape files (produced from card decks at the University of Hawaii computer) can be either entered at the Coast Guard terminal or mailed to the Southwest Center's La Jolla headquarters and entered there. Additionally, the Coast Guard terminal has remote disk file creation capability which could be used for original Laboratory data entry.

Central INFONET data files can be stored off-line on tape or on-line - appropriate for editing or frequent access - on disk. Verification and validation can be accomplished from Honolulu Laboratory terminals.

The University of Hawaii IBM 370/175 based computer system, the largest in Hawaii, provides local Honolulu Laboratory data processing capability. Data entry is either by remote entry of original data (interactive CRT or printing terminal) or, for large files, by cards punched at the Laboratory. Disk and tape storage is available. Verification and validation can be accomplished from Laboratory terminals. An important limitation of the system is the increasingly long turn-around time experienced by NMFS users as a result of their low priority status, behind students and University of Hawaii administrative staff.

A first option for NMFS-collected data reduction, local reduction, can be accomplished with current capabilities. Data entry, as well as verification and validation, are well within NMFS-Honolulu Laboratory capabilities. Timeliness of Council file updating can be expected to be excellent.

A second option, central reduction of Council-needed data, should be possible with the addition of approximately .5 man-year's labor and .5 machine-years of data entry/editing machinery.

There are no qualitative caveats to local reduction. Local reduction is ranked first; central reduction second.

Table 42 summarizes results of the foregoing assessment of local versus central reduction of Council-needed, locally collected catch/ effort data. Entries suggest that local reduction of Council-needed data is appropriate for Guam - Northern Marianas - and NMFS - collected data; central Council-reduction for American Samoa - and Hawaii-collected data.

Table 42. Estimated costs and rankings of local and central reduction alternatives for Council-needed, agency-collected data.

See text for discussion

Collecting Agency	Reduction Alternatives							
	Local				Central			
	Cost				Cost			
	C1*	C2	Q	Rank	C1	C2	Q	Rank
American Samoa	0.10	0.10	-	2	0.10	0.10	+	1
Guam	.00	.00	+	1	0.50	0.50	+	2
Hawaii	1.00	1.00	-	2	0.75	0.75	+	1
No. Marianas	0.25	0.25	-	2	0.25	0.25	+	1
NMFS	.00	.00	+	1	0.50	0.50	+	2

*/ Symbols: C1 = data processing labor cost in man-years.
C2 = data entry/editing equipment cost in machine-years.
Q = qualitative factor reflecting non-quantifiable measures of capability.

6.4 DATA COLLECTION FORMS

6.4.1. Guam Fisheries

6.4.1.1. Aerial Fisheries Survey

6.4.1.2. Inshore Fishermen Interview and Creel Census

6.4.1.3. Offshore Recreational Fishing Census

6.4.2. Hawaii Fisheries

Hawaii Division of Fish and Game Forms:

6.4.2.1. Aku Catch Report

6.4.2.2. Application for Vessel Registration

6.4.2.3. Aquarium Fish Catch Report

6.4.2.4. Commerical Fishing License

6.4.2.5. Fish Catch Report

6.4.2.6. Fish Dealer's Report on Purchases of Fish and Shellfish

6.4.2.7. Flagline Catch Report

6.4.2.8. Green Sea Turtle Catch Report

6.4.2.9. Pond Operator's Monthly Fish Report

National Marine Fisheries Service Forms for Hawaii:

6.4.2.10 Commercial Fish Catch Report

6.4.2.11. Crustacean Tagging and Morphometric Form

6.4.2.12. Daily Catch Report - Handline Fishing

6.4.2.13. Demersel Catch Form

6.4.2.14. Standardized Surface Trolling Data Sheet

6.4.2.15. Commercial Trap, Pot, and Net Report

6.4.3. Northern Marianas Fisheries

6.4.3.1. Application for Municipal Business

6.4.3.2. Application for Registration and Number for Vessel

6.4.3.3. Purchase Slip

6.4.3.4. Sales Slip

6.4.4. United States Coast Guard

6.4.4.1. Certificate of Admeasurement

AERIAL FISHERIES SURVEY

DATE _____ FLIGHT NO. _____ SKY STATE _____ WIND _____
 SEA STATE _____ TAKE OFF TIME _____ LANDING TIME _____ OBSERVER _____

	Census Regions												Total # Animals	Total # Persons	Total # Boats
	1	2	3	4	5	6	7	8	9	10	11	12			
Turtles															
Sharks															
Pole Fishing															
Cast Netting															
Spearing															
Gill/Sur- round Netting															
Spinning															
Bottom Boats															
Trolling Boats															
Unidentified Persons															
Unidentified Boats															
Totals															

-110-

NOTE: Prior to 1977, there were 12 regions.

DIVISION OF FISH AND WILDLIFE
DEPARTMENT OF AGRICULTURE
GOVERNMENT OF GUAM

INSHORE FISHERMEN INTERVIEW AND CREEL CENSUS

Tide: _____ Sky State: _____ Date: _____ 19____

Wind: _____ Sea State: _____ Time of Interview: _____

Area: _____ Reef Zone: _____

Type of Fishing: Hook and Line: _____, Throw-net: _____ Spear: _____

Shrimp trawl net: _____, Gill net: _____ Spinning: _____ Other: _____

No. of Fishermen: _____ Interviewer: _____

Time Started Fishing: _____ Estimated Time Stop Fishing: _____

Bait used (if any): _____ Preferred Fish: _____

[illegible]

[illegible]

STATE OF HAWAII
DEPARTMENT OF TRANSPORTATION, HARBORS DIVISION
79 South Nimitz Highway, Honolulu, Hawaii 96813

(1) TYPE OF REGISTRATION (Circle One) 1. NEW 2. TRANSFER OF OWNERSHIP
(2) NUMBER NOW ON OR AWARDED TO THIS VESSEL (If none so state)

(3) NEW OWNER'S LAST NAME	FIRST	MIDDLE	(3a) TELEPHONE NO. HOME: BUS.:
(4) RESIDENCE AND MAILING ADDRESS	STREET/POST OFFICE BOX		(4a) EMPLOYED BY
(5) CITY POST OFFICE	STATE	ZIP CODE NO.	(6) DATE OF BIRTH
(7) CO-OWNER'S LAST NAME	FIRST	MIDDLE	(7a) TELEPHONE NO.
(8) RESIDENCE AND MAILING ADDRESS	STREET/POST OFFICE BOX		(8a) EMPLOYED BY
(9) CITY POST OFFICE	STATE	ZIP CODE NO.	(10) DATE OF BIRTH

(18) PLACE KEPT (Complete 1 or 2) WHEN NOT IN USE VESSEL IS USUALLY: 1. MOORED AT (Island and Harbor)

(19) TYPE OF VESSEL (Circle One)	1. CABIN MOTORBOAT	2. OPEN MOTORBOAT	3. RUNABOUT
(4) AUXILIARY POWERED SAILING VESSEL	5. SAILING VESSEL		
(6) MOTOR VESSEL (MORE THAN 65' IN LENGTH)	7. OTHER (Describe)		

(24) VESSEL LENGTH FEET INCHES	(25) HULL MATERIAL (Circle One)	1. WOOD	2. STEEL
	3. FIBERGLASS/PLASTIC	4. ALUMINUM	4a. RUBBER/FABRIC
	5. OTHER		

(29) HULL IDENTIFICATION NUMBER, IF NONE OR OBLITERATED, SO STATE.	(30) TYPE OF FUEL (Circle One)	1. GASOLINE	2. DIESEL	3. OTHER
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(32) PRINCIPAL USE (Circle One)	1. PLEASURE	2. COMMERCIAL FISHING	3. CHARTER FISHING
6. LIVRY	7. DEALER	8. MANUFACTURER	9. FEE EXEMPT YOUTH GROUP

(13) AUTHENTICATION. THIS SECTION MUST BE COMPLETED BY ALL APPLICANTS. I/We hereby certify under penalty of law that the information given by me/us on this application is true, correct and complete to the best of my/our knowledge and belief.

Signature(s)	Date(s) Signed
Owner _____	_____
Co-owner _____	_____
Co-owner _____	_____

APPLICATION FOR VESSEL REGISTRATION AND
CERTIFICATE OF NUMBER
For Undocumented Vessel Principally Used in Hawaii

(11) LIEN HOLDER—MORTGAGEE (Attach separate sheet if necessary)	(12) DATE OF LIEN	
(13) STREET ADDRESS OR BOX NUMBER	(12a) DATE LIEN SATISFIED	
(14) CITY POST OFFICE	STATE	ZIP CODE NUMBER
(15) CITIZENSHIP OF OWNER/S (Circle One)	(16) RADIO COMMUNICATIONS (Circle One)	
U.S.A. ALIEN IF ALIEN GIVE COUNTRY	1. NONE 2. SENDING 3. RECEIVING 4. BOTH	5. RADIO CALL LTRS
(17) IF THE VESSEL HAS BEEN AWARDED AN OUT-OF-STATE NUMBER, ATTACH THE REGISTRATION DOCUMENTS ISSUED BY THAT STATE OR COUNTRY IF AVAILABLE AND COMPLETE THE FOLLOWING: 1. VESSEL ENTERED HAWAII (DATE) _____ 2. VESSEL FIRST OPERATED IN HAWAII (DATE) _____		

2. STORED ON LAND AT (Island)

(20) NUMBER OF HULLS	(21) COLORS 1. HULL: _____ 2. CABIN TOP &/OR DECK: _____ 3. TRIM: _____	(22) NAME OF VESSEL	(23) YEAR BUILT (23a) YEAR MO-DEL
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(26) ENGINE 1. MANUFACTURER _____ 2. SERIAL NO. _____	(27) HULL MANUFACTURER'S NAME	(28) COUNTRY WHERE HULL BUILT
--	-------------------------------	-------------------------------

(31) PROPULSION (Circle One)	1. OUTBOARD	2. INBOARD	3. INBOARD/OUTBOARD
4. SAIL ONLY	5. SAIL & INBOARD	6. SAIL & OUTBOARD	7. MANUAL 8. OTHER
4. COMMERCIAL PASSENGER		5. OTHER COMMERCIAL	
9. FEE EXEMPT YOUTH GROUP		10. FEE EXEMPT—GOV'T. 11. OTHER (Describe)	

Please send Check or Money Order payable: Harbors Division
PLEASE DO NOT MAIL CASH

FOR HARBORS DIVISION USE ONLY		Subscribed before
me this _____ day of _____, 19____ (Signature)		
DATE PROCESSING COMPLETED		By _____
EXPIRATION DATE		

INFORMATION ESTABLISHING PROOF OF OWNERSHIP

The "Certificate of Sale" is to be completed by the seller unless he gives the buyer a "Bill of Sale". The "Affidavit of Applicant" is to be completed by the purchaser if the seller did not complete the "Certificate of Sale" or the applicant has no other evidence of ownership. Do not complete the "Affidavit of Applicant" if a document showing that the vessel was registered by the applicant in another state is attached.

The Department, if not satisfied with the evidence submitted as proof of ownership, may require additional information or documents issued by that state if available. Application to register a vessel which has been registered in another state must be accompanied by the registration documents.

CERTIFICATE OF SALE
(To Be Completed By Seller)

I/WE (Seller's Name) _____

(Circle One) 1. DEALER 2. BUILDER/MANUFACTURER 3. OTHER _____

ADDRESS _____

TRANSFERRERED (Circle One) 1. ALL 2. PART INTEREST IN THE VESSEL DESCRIBED ON THE REVERSE SIDE OF _____

THIS FORM ON (Day, Month, Year transferred) _____

AT (City or County/State) _____

TO THE FOLLOWING PERSON(S) Name(s) _____

AND IS FREE OF ALL ENCUMBRANCES EXCEPT ANY SHOWN ON THE REVERSE OF THIS FORM.

I/WE HEREBY CERTIFY UNDER PENALTY OF LAW THAT THE FOREGOING IS TRUE AND CORRECT.

Signature(s) of Seller(s) _____

Date(s) Signed _____

AFFIDAVIT OF APPLICANT

I/WE DECLARE THAT (Circle One) 1. ALL 2. PART INTEREST IN THE VESSEL DESCRIBED ON THE

REVERSE SIDE OF THIS FORM WAS ACQUIRED BY ME FROM (Name and Address of previous owner) _____

IN THE FOLLOWING MANNER: (Circle One)

1. PURCHASE 2. TRADE/SWAP 3. GIFT 4. OTHER (Specify) _____

AT (City or County/State where acquired) _____

ON (Day, Month, Year acquired) _____

I/WE CERTIFY UNDER PENALTY OF LAW THAT THE FOREGOING IS TRUE AND CORRECT.

Signature(s) _____

Date(s) Signed _____

OWNER _____

CO-OWNER _____

CO-OWNER _____

AFFIDAVIT OF VESSEL REGISTRAR

The applicant presented satisfactory evidence of ownership of the vessel described in this application in the form of _____

which was examined by me and returned to the applicant.

Signature _____

Date _____

DECLARATION OF JOINT OWNERSHIP

WE, THE UNDERSIGNED, DO HEREBY DECLARE THAT THE OWNERSHIP OF VESSEL NO. _____ IS HELD IN OUR JOINT NAMES AS JOINT TENANTS, WITH RIGHTS OF SURVIVORSHIP AND NOT AS TENANTS IN COMMON.

SIGNATURE _____

DATE _____

SIGNATURE _____

DATE _____

See Instructions on Inside of Cover

AQUARIUM
FISH CATCH REPORT

Date _____
LAST FIRST M.I.

Aquarium Permit No. _____

Line Fished _____ Month Fished _____, 19____

Commercial Fisherman Yes _____ No _____

Total No. of Days Fished _____

Totals are for all
persons included
on this form.

If yes, License No. 7 -

Total No. of Hours Fished _____

Includes actual dive time,
snorkel time, shoreline time, etc.

Species	Computer Code Division Use Only	Ave. Depth (ft.)	Total Caught	Commercial Fishermen Only			
				Export		Local	
				No. Sold	Total Value	No. Sold	Total Value
MILY CHAETODONTIDAE							
Holocanthus arcuatus	8554575201						
Centropyge potteri	8554575303						
C. flammeus	8554575304						
C. fisheri	8554575301						
Heniochus acuminatus	8554570502						
Hemitaurichthys zoster	8554570602						
Forcipiger longirostris	8554570401						
Forcipiger flavissimus	8554570101						
Chaetodon fremblii	8554570701						
C. reticulatus	8554570702						
C. corallicola (kleini)	8554570703						
C. ephippium	8554570705						
C. auriga	8554570706						
C. unimaculatus	8554570707						
C. lunula	8554570708						
C. trifasciatus	8554570710						
C. ornatissimus	8554570711						
C. quadrimaculatus	8554570712						
C. multicinctus	8554570713						
C. milgari	8554570715						
C. tinkeri	8554570704						
C. lineolatus	8554570709						
MILY LABRIDAE							
Bodianus bilunulatus	8555070201						
Labroides phthirophagus	8555070401						
Gomphosus varius	8555071501						
Cirrhilabrus jordani	8555070601						
Pseudochelinus octotaenia	8555070802						
P. cyanidus	8555070801						
Cheilinus bimaculatus	8555070702						
Thalassoma duperreyi	8555071405						
T. ballieui	8555071407						
Iniistius pavoninus	8555071103						
Coris flavovittata	8555071601						
C. ballieui (rosea)	8555071605						
C. venusta	8555071603						
C. gaimardi	8555071604						
Pseudojulis cerasinus	8555071701						
Stethojulis balteata (axillaris, albovittata)	8555071801						
Cheilio inermis	8555070101						
Macropharyngodon geoffroyi	8555072001						
Anampses rubrocaudatus	8555072101						
A. cuvieri	8555072102						
A. chrycephalus	8555072101						
Halichoeres ornatissimus	8555072201						
MILY POMACENTRIDAE							
Dascyllus albisella	8554640101						
D. trimaculatus	8554640104						
Abudefduf abdominalis	8554640202						
A. sordidus	8554640201						
A. imparipennis	8554640203						
Chromis ovalis	8554640502						
C. leucurus	8554640503						
C. verator	8554640504						
Pomacentrus jenkinsi	8554640401						
MILY HOLOCENTRIDAE							
Holocentrus diadema	8546180105						
H. xantherythrus	8546180107						
Myripristis argyromus	8546180404						
MILY ACANTHURIDAE							
Acanthurus achilles	8555690103						
A. olivaceus	8555690109						
A. glaucopareus	8555690104						
A. mata	8555690112						
A. sandvicensis	8555690101						
A. dussumieri	8555690110						
A. nigrofasciatus	8555690107						
Naso unicornis	8555690404						
N. lituratus	8555690401						
Ctenochaetus strigosus	8555690201						

Species	Computer Code	Ave. Depth (ft.)	Total Caught	Commercial Fishermen Only			
				Export		Local	
				No. Sold	Total Value	No. Sold	T V
Zebrasoma flavescens	8555690301						
Z. veliferum	8555690302						
FAMILY BALISTIDAE							
Balistes bursa	8558020501						
Melichthys vidua	8558020402						
M. boniva	8558020401						
Rhinacanthus rectangulus	8558020201						
R. aculeatus	8558020302						
Xanthichthys ringens	8558020201						
FAMILY MONACANTHIDAE							
Pervagor spilosoma	8558025201						
Amanses carolae	8558025502						
Alutera scripta	8558025102						
FAMILY CIRRHITIDAE							
Paracirrhites arcatus	8554660101						
P. fosteri	8554660102						
P. cinctus	8554660401						
Cirrhites alternatus	8554660201						
Oxyrrhites typus	8554660301						
FAMILY MURAENIDAE							
Echidna zebra	8522050201						
E. nebulosa	8522050202						
Gymnothorax flavimarginatus	8522050605						
G. meleagris	8522050506						
G. eurostus	8522050607						
Murzena pardalis	8522050401						
Uropterygius knighti	8522050304						
CELLANEUS							
Abantennarius analis	8541070101						
Antennarius drombus	8541070303						
Arothron hispidus	8558060302						
A. meleagris	8558060301						
Autostomus chinensis	8549060101						
Apogon brachygrammus	8554180426						
Caesioperca thompsoni	8554020503						
Canthiaster cinctus	8558060101						
C. jactator	8558060102						
Cheilodactylus vittatus	8554690101						
Dactyloptena orientalis	8553010107						
Dendrochirus brachypterus	8552010301						
Diodon hystrix	8553080201						
Exallias brevis	8555340101						
Kuhlia sandvicensis	8554140101						
Lactoria fornasini	8558030301						
Microcanthus strigatus	8554530301						
Ostracion lentiginosus	8558030201						
Pterois sphex	8552010201						
Parupeneus porphyreus	8554470303						
P. multifasciatus	8554470305						
P. pleurostigma	8554470301						
Scorpaenopsis gibbosa	8552010701						
S. cacopsis	8552010702						
Scorpaena conrorta	8552011101						
Taenianotus tricanthus	8552010101						
Zanclus canescens							
ERTEBRATES							
Isaurus elongatus	3756010101						
Conus textile	7023320106						
Cypraea caputserpentis	7022840113						
Acanthaster planci	7832030101						
Heterocentrotus mammillatus	7852240301						
Stenopus hispidus	6485110101						
Hymenocera elegans	6483330201						
Hippolysmata acicula	6483430102						
Saron marmoratus	6483430301						

FD-1 (Rev. 7/77)

State of Hawaii

DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF FISH AND GAME

LICENSE NO. 78 -

Exp. Date: Date of Issue to June 30, 1978

1 ☐ NEW
2 ☐ RENEWALCOMMERCIAL FISHING LICENSE
1977 - 1978LICENSE FEE
1 ☐ RESIDENT* \$10.00
2 ☐ NON-RESIDENT \$20.00

Name (Last, First, Middle Initial)		Sex	Birth Date	Weight	Height	Color of Hair	Color of Eyes
Mailing Address		City	County/State	Zip		Zip	
Reference		Street No. & Name	City	County/State	Zip		Home Phone
Date Recd.		Length of Residence in Hawaii	U.S. Citizen?	Business Phone		1 ☐ Yes 2 ☐ No	
CHECK ONE:		PRIMARY TYPE OF FISHING (Check no more than 2)					
1 ☐ CREW MEMBER		☐ AQUARIUM ☐ FISH POND ☐ MAR. (WATER) GARDEN, ETC. ☐ HANDLINE (OVERSEA, INSIDE) ☐ LONGLINE (AMERICAN, FOREIGN) ☐ NETS ☐ SPECIFY (GILL NETS, TRAWL, PURSE SEINE, JAPAN, ETC.) ☐ POLE & LINE (AMERICAN, FOREIGN) ☐ TRAPS (POLE) ☐ TIGLING ☐ OTHER					
2 ☐ BOAT CAPTAIN		Name of Boat: _____ Date of Build: _____ H.A. No.: _____ Documented No.: _____ Number of Crew: _____ Port of Anchorage: _____ IS SHORELINE FISHERMAN? ☐					
Monthly Fish Catch Report Required? 1 ☐ Yes 2 ☐ No		SIGNATURE OF LICENSEE _____ I am: ☐ Minor Below Age 18 ☐ PARENT OR GUARDIAN VALIDATION (FISH AND GAME USE ONLY) AGENT _____ DATE _____ ISLAND _____					

*ANY PERSON WHO HAS RESIDED IN THE STATE FOR ONE YEAR OR LONGER IN HAWAII REVISOR'S STATUTES 189-2

DIVISION OF FISH AND GAME

Fish Dealer _____

Phone No. _____

Business Address _____

The above report is true, correct, and complete to the best of my knowledge and belief.

• **Time** 10:00 AM

Signature _____

NOTE: The law requires this report to be filed on or before the tenth day of each month.

Mail to: DIVISION OF FISH AND GAME
office on your island

FLAGLINE CATCH REPORT

Name of Permittee

License No.

Month

19

Name of Boat.

2.6

No. of Baskets Used

[illegible][illegible]

BAIT REPORT

[illegible]

The reports contained hereon are true, correct, and complete to the best of my knowledge and belief.

Signature _____

Permittee or Authorized Agent

• if several iterations are taken on a trip, which are listed

Division of Fish and Game
1151 Punchbowl Street
Honolulu, Hawaii 96813

REMINDER: This report must be submitted no later than 10 days following the end of the month. If no turtles are caught during the month, write "NO CATCH" across the report form.

COMMERCIAL FISH CATCH REPORT

[illegible]

LOCATION: Latitude and longitude desired. An alternative is a general location consisting of radar distance and compass bearing, i.e., 5 miles 45° NE of island. Use a new log sheet if the position is changed during the day.

TIME STARTED: Enter the time gear enters the water.

TIME ENDED: Enter the time gear is hauled out of the water.

DEPTH: Enter depth in fathoms. If depth varies, enter average depth.

BAIT: Enter kind of bait used.

ACTIVITY: Circle either (1) for Handline fishing, (2) for Trap, Pot and Net fishing, or (3) for Trolling.

Handline Fishing:

- No. of lines Enter number of lines fishing.
- No. of hooks/line Enter number of hooks per line.

Trap, Pot, or Net Fishing:

- No. of strings Enter number of strings. (A string is an array of traps, pots, or nets or individually set gear).
- No. traps, pots, or nets/string Enter number of traps, pots, or nets attached to each string. If the number of gear per string varies, enter average number. If both string(s) and individually set gear are used, enter total number of gear.
- Distance between gear Enter distance between trap, pots, or nets. If distance varies, enter the average.

Trolling:

- No. of lines Enter number of lines out.
- Type(s) of lure(s) Describe type(s) of lure(s) used.

SPECIES CAUGHT: List all species caught. Incidental catches are also desired information.

TOTAL NUMBER: Use either the estimated or actual column.

- Estimated enter estimated number of pieces.
- Actual enter exact number of pieces caught.

TOTAL WEIGHT: Use either the estimated or actual column.

- Estimated Enter estimated total weight.
- Actual Enter exact actual weight. Usually, this cannot be done at sea.

REMARKS:

Three dashed columns have been added for lobsters. - Enter the number of legal size lobsters under the column "L". Enter number of short lobsters under "S" column. Enter number of berried lobsters under the "B" column.

Capture: Station	Position	Release: Station	Position

Appendix 6.4.2.11. 123

SPECIES

1. Panulirus penicillatus (spiny lobster, four spines between antenna base).
2. Panulirus marginatus (spiny lobster with two spines between antenna base).
3. Scyllarides squammosus (slipper lobster).
4. Ranina ranina (Kona crab).
5. Portunas sanguinolentus (white crab).

CARAPACE LENGTH

Along the midline from between the eyes to the end of carapace.

CARAPACE WIDTH

Maximum width of carapace (not including spines).

TAIL LENGTH

Measured along midline to include length of abdomen and tail.

SEX

Male: Sperm pore present at the base of the fifth leg.

Female: Pore present at the base of the third leg. Frequently a sperm plate extends between the third and fifth legs.

OVA COLORS FOR BERRIED CONDITION

1. Orange
2. Brown
3. White

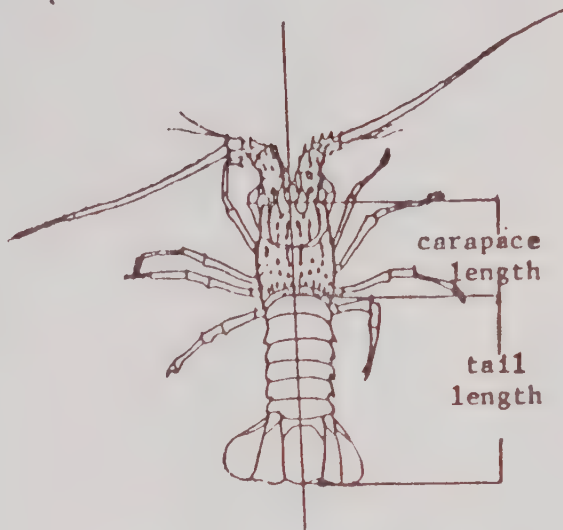
CONDITION OF SPERM PLATE

1. Whitish brown
2. Brown smooth
3. Brown rough

MISSING OR BROKEN APPENDAGES

Circle the appropriate missing appendages using the following codes:

<u>Code</u>	<u>Appendages</u>	<u>Code</u>	<u>Appendages</u>
R	Right	1	First leg
L	Left	2	Second leg
A	Antenna	3	Third leg
a	Antennules	4	Fourth leg
		5	Fifth leg



CONTROL NO. 18
1-2

NATIONAL MARINE FISHERIES SERVICE
SOUTHWEST FISHERIES CENTER, HONOLULU LABORATORY
HONOLULU, HAWAII 96812

DEMERSEL CATCH FORM

3-5	6-9	10-15	TRAWL TIME	16-17	18-19			
VESSEL	CRUISE	DATE		OVERBOARD	ON BOTTOM	START RETRIEVAL	ELAPSED	ON SURFACE

20	21-24	25-28	29-31	32-33	34-35
OCT	LAT (START)	LONG (START)	LAT (END)	LONG (END)	STATION NO.

LORAN (START)	LORAN (END)	TEMP °C	36-38	39-41	42-45	46-49
			SURFACE	BOTTOM	BOTTOM SALINITY	XBT. NO.

BOTTOM DEPTH	42-45	46-49
	START	END

50-51	52
DESCRIPTION	CLOUD COVER
	WIND DIR.
	WIND FORCE
	SEA

53-55	56-58	59-60	61-62	63
SCOPE	RPM	GEAR TYPE	DOOR & ACCESS.	PERFORMANCE

64
MODEL / FREQ.
RANGE
VOL.
PULSE
TRACE DESCRIPTION

REMARKS _____

[illegible]

STANDARDIZED SURFACE TROLLING DATA SHEET

VESSEL _____ CRUISE NO. _____ DATE _____ TIME ZONE _____

EN ROUTE FROM: LAT _____ LONG. _____ TO: LAT _____ LONG. _____

OR OFF: _____ LAT _____ LONG. _____ TOTAL HOURS TROLLED _____

OPERATION

[illegible]

CATCH

[illegible]

- STRING No. - An assembly of traps, pots, or nets attached to a mainline. If there is more than one string per station, use a separate form for each string. Each string, when set in close proximity, should be numbered consecutively as they are retrieved.
- GEAR No. - Assign numbers consecutively to gear attached to a string.
- DEPTH - Record the average depth of the string.
- LOCATION - Obtain a position fix by either longitude or latitude, Loran readings, two- or three-point compass fix, or a compass reading and an estimate of distance (by radar) from an island.
- GEAR - Fish traps, shrimp traps, lobster pots, crab nets, etc.
- SPECIES - Try to use the following codes for species caught. For other species, please specify.

<u>Code</u>	<u>Local name</u>	<u>Common name</u>	<u>Scientific name</u>
FISH			
61-01	A'awa	Spotted wrasse	Bodianus bilunulatus
27-90	Alaihi	Squirrelfish	Holocentrus sp.
100-00	Aweoweo	Red bigeye	Priacanthidae
57-01	Hapuupuu	Sea bass	Epinephelus quernus
61-27	Hinalea luahine	Wrasse	Thalassoma ballieui
71-00	Fugu	Puffer	Tetradontidae
59-01	Kumu	Red goatfish	Parupeneus porphyreus
59-03	Malu	Goatfish	Parupeneus pluerostigma
65-01	Manini	Surgeonfish	Acanthurus sandvicensis
59-02	Moano	Goatfish	Parupeneus multifasciatus
69-01	O'ili uwiwi	Filefish	Pervagor spilosoma
58-01	Opakapaka	Pink snapper	Pristipomoides microlepis
55-11	Pig ulua (buta)	Thicklip ulua	Caranx cheilio
16-00	Puhi	Moray eel	Muraenidae
15-00	Puhi-uha	White eel	Congridae
58-03	Taape	Blueline snapper	Lutjanus kasmira
58-05	Ulaula (ehu)	Red snapper	Etelis marshi
55-16	Ulua	White ulua	Carangoides ajax
23-01	Upapalu	Cardinalfish	Apogon snyderi
27-01	Uu (menpachi)	Squirrelfish	Myripristis berndti
59-04	Weke-ula	Red goatfish	Mulloidichthys auriflamma

CRUSTACEAN AND MOLLUSK

410-01	'Ala-kuma	Spotted pebble crab	Carpilius maculatus
500-01	Hee (tako)	Octopus (day)	Polypus marmoratus
500-02	Hee (tako)	Octopus (night)	Polypus ornatus
402-01	Kona crab	Kona crab	Ranina ranina (serrata)
403-01	Kuahonu	White crab	Portunus sanguinolentus
405-01	Opae	Shrimp	Heterocarpus ensifer
405-02	Opae	Shrimp	Heterocarpus laevigatus
404-01	Opaelolo	Shrimp	Penaeus marginatus
408-00	Poki-poki	Box crab	Calappa sp.
401-01	Ula	Spiny lobster	Panulirus marginatus
401-02	Ula	Green lobster	Panulirus penicillatus
400-01	Ulapapapa	Slipper lobster	Scyllarides squammosus
406-00	Una-una	Hermit crab	Paguridae

NORTHERN MARIANA ISLANDS
OFFICE OF THE MAYOR
P. O. BOX 325
SAIPAN, MARIANA ISLANDS
9 6 9 5 0

APPLICATION FOR MUNICIPAL
BUSINESS

SAIPAN MUNICIPAL BUSINESS LICENSE OFFICER
A: ECONOMIC DEVELOPMENT OFFICER, SAIPAN MUNICIPAL GOVERNMENT
TREASURER, SAIPAN MUNICIPAL GOVERNMENT

THE UNDERSIGNED HEREBY makes application for the following Municipal License
to engage in or continue, in the "Operation of Business", in the Municipality of
Saipan as defined in Municipal Ordinance No. 21-10-68, Section 1 thru Section 10.
May it be individual, co-partnership, cooperative, club or others: _____

S P E C I F Y

Type of Business: _____

As required by this Ordinance for the issuance of such License, the applicant makes
the following statements:

1. Applicant's full name: _____

2. Name of Business: _____

3. Applicant is a (an) _____
(Individual; co-partnership; cooperative, club)

(Other not specify above).

4. Location of Business: _____

5. District No. _____ Lot No. _____

6. Applicant is residing at _____ is _____
of age; is the owner of "Proposed Business to be Licensed"; and is a person
of good morals and business standing.

7. No person other than the applicant named herein will have any interest in the
business or license affected by this application without prior recommendation
of the Municipal Government and approval of such interest by the Mayor or his
duly representative.

8. Applicant is familiar with the provisions of the Ordinance relating to 21-10-68.

9. That prior to issuance of license applicant will submit such Public Health
Clearance Certificate(s) and other requirements as may be required by law as
a condition of issuing the license.

I, the APPLICANT, hereby certify that the statements contained herein are true and
correct. I further agree that any license issued to me in response to this appli-
cation will be granted and accepted by me upon condition that I fully comply with
laws, rules and regulations now or hereafter applicable to my business and that I
pay all assessed taxes and fees when due to the Municipal Treasurer.

Date: _____ 19 _____ Signature of Applicant _____

APPLICATION FOR REGISTRATION AND NUMBER FOR VESSEL
BOARD OF MARINE INSPECTOR.
TRUST TERRITORY OF THE PACIFIC ISLANDS

Name of Vessel _____ NO: _____
(for use of Dist. Admin)

Name of Owner _____ Address _____
(Last, First, Middle)

Usual location of vessel _____

Type of Vessel _____ Number now on vessel _____

Service _____ Year completed _____

Tonnage _____ W/T or M/T cargo _____ Cruising Radius _____

Length _____ Rig _____ Beam _____ ft. Draft _____ ft.

Capacity _____ Passenger _____ Construction (wood, steel, etc) _____

Builder _____ Place built _____

Engine: Maker _____ Serial No. _____ H.P. _____

-129-

I certify that the statements herein made are true and that the boat described is
owned by: _____
f _____

Signature (Owner or authorized agent) _____

PURCHASE SLIP

NO.

0497

COMPANY

DATE _____

BOAT OR
FISHERMAN

CO-OP NO

REMARKS

SP	LOCAL NAME	ENGLISH NAME	UNIT PRICE	UNIT	AMOUNT
105	ATULAJ	MACKEREL			
308	BUHA	SNAPPER			
489	GADAO PENTU	GROUPE			
253	GADDAS	GIANT WRASSE			
601	HAGGAN	TURTLE			
007	HUGUPAO	SURGEON			
541	ALU	BARRACUDA			
524	HITING	RABBITFISH			
522	HITING FEDA	RABBITFISH			
461	KACHUG	YELLOWFIN TUNA			
457	KACHO	SKIPJACK TUNA			
433	LAGGUA	PARROTFISH			
363	LAIGUAN	MULLET			
284	MAFUTE	SNAPPER			
926	MAHONGAN	LOBSTER			
218	SAGAMELON	SQUIRRELFISH			
452	SAOWARA	WAHOO			
525	SESJUN	RABBITFISH			
099	TARAKITO	CREVALLY			
021	TATAGA	UNICORN			

WEATHER: (CHECK ONE)

1. ☐ GOOD 2. ☐ FAIR 3. ☐ POOR 4. ☐ RAINY

TOTAL

3715

THE UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
U. S. COAST GUARD

Port of Certificate No. (Date)

CERTIFICATE OF ADMEASUREMENT

I CERTIFY that an admeasurement has been made of the vessel described below:

Nationality.....	Builder's Hull No.....
Rig.....	Decks.....
Name.....	Masts.....
Port.....	Stem.....
Official No.....	Stern.....
Built by.....	Register length.....feet
When built (year completed).....	Register breadth.....feet
Place of build.....	Register depth.....feet
State.....	Register height.....feet
Material.....	

Capacity under tonnage deck ¹(Forepeak.....Afterpeak.....)		
Capacity between decks, above tonnage deck.....		
Capacity of enclosures on the upper deck, viz:		
Forecastle.....	Deckhouses.....	Excess hatchways.....
Bridge.....	Side houses.....	Light and air ²
Poop.....	Mast houses.....	
Break.....	Trunks.....	
GROSS TONNAGE.....		
Deductions under Section 4153, Revised Statutes, as amended (Section 77, title 46, United States Code):		
Crew space.....	Anchor gear.....	Donkey engine and boiler.....
Master's cabin.....	Boatswain's stores.....	Radio house.....
Steering gear.....	Chart house.....	Storage of sails.....
Propelling power (actual space.....)	%.....	
TOTAL DEDUCTIONS.....		
NET TONNAGE.....		X X X

The following-described spaces, and no others, have been omitted, viz:

Forepeak.....	Companions.....
Afterpeak.....	Galley.....
Other spaces (except double bottoms) for water ballast.....	Skylights and air shafts <i>not over</i> propelling machinery.....
Open forecastle.....	Wheelhouse.....
Open bridge.....	Water closets.....
Open poop.....	Anchor gear.....
Open shelter deck.....	Donkey engine and boiler.....
Open houses.....	Steering gear.....
Passenger cabins.....	Light and air over propelling machinery.....
	Other machinery spaces.....

Admeasurer.....

Officer in Charge, Marine Inspection.....

I agree to the above description and admeasurement.

(SEAL)

Owner, Master, or Agent.....

¹ Give tonnage of each peak tank used other than for water ballast, which is included herein.² These spaces are to be added to tonnage only by permission of the Officer in Charge, Marine Inspection.

6.5. PROPOSAL FOR A PILOT LOGBOOK STUDY



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

September 26, 1977

To: W. G. Van Campen, Executive Director, WPRFMC
From: Richard S. Shomura, Director, Honolulu Laboratory
Subject: Proposal for a logbook pilot study

Enclosed is a proposal that the Council may wish to consider for support. I believe we all agree that good catch and effort statistics need to be collected from the recreational fishing sector operating in the Council's area. If done properly the pilot study will tell us if a voluntary log-book system will do the job.

I would like to recommend that the Council have the SSC review and evaluate this proposal.

Enclosure

PROPOSAL FOR A LOGBOOK PILOT STUDY

This is a proposal for a pilot study to obtain information needed to institute a logbook system for the purpose of collecting catch and effort data from recreational fishing boats. This proposal was written for the Western Pacific Regional Fishery Management Council (WPRFMC) to implement.

Background

The Fishery Conservation and Management Act of 1976 directs the determination of optimum yields for fisheries which are predominantly located within the 3 to 200-mile zone. This directive has made urgent the need for data on the biology, economics, and fishery operations of the pertinent fisheries. In the central and western Pacific Ocean the principal fish species covered by the Act are mahimahi, ono, and the billfishes. The billfishes include blue marlin, striped marlin, black marlin, shortbill spearfish, swordfish, and sailfish.

This is a pilot study of a logbook system which will encompass the areas of jurisdiction of the WPRFMC which are Hawaii, American Samoa, Guam, and the Northern Marianas. The pilot study itself will be limited to the Island of Oahu. This logbook system primarily addresses the need for data on total effort, catch, and catch per unit of effort of the recreational fisheries for the aforementioned species. These data are of foremost importance for management purposes. Although it does not address the needs for biological and economic data, some biological information will result from it. Because certain tunas--yellowfin, skipjack, kawakawa, frigate mackerels--are also caught by these recreational fishermen, data on tunas will be collected although the Act does not include tunas.

Because most of the billfish species have the potential for transoceanic migrations, data from areas other than the areas under WPRFMC jurisdiction will be eventually needed to complete the information needs. The logbook system that is being developed here can be used with minor adaptations in other centers of recreational billfish fishing in the Pacific. A common logbook for all areas would be the basis for uniformity in data collection and assure comparability among areas.

A logbook system is not the only method to collect the required data on effort and catch. The data may be collected by enrolling key persons in fishing clubs to do the work or by stationing personnel at all boat ramps to interview fishermen as they return from a day's fishing. The disadvantages in the former method are: (1) the quality and reliability of the data will differ from club to club and (2) not all recreational fishermen belong to a club. The barrier to interviews of fishermen at boat ramps is its prohibitive costs. The overriding advantage of a logbook system over the other methods is that with proper adherence to rules of statistical

sampling, the results obtained from a fraction of the fleet may be projected to obtain estimates of total effort and catch within desired confidence limits. The other methods do not lend themselves to compliance with sampling rules.

Data on billfish catches by commercial fishermen for the past 30 years are available from the Hawaii State Division of Fish and Game (HFG) which requires monthly catch reports from all who have purchased licenses to sell fish. A sizeable portion of the ono, mahimahi, and billfish (except swordfish) catches is made by recreational trollers. No organization collects data on this group of fishermen on a systematic continuing basis. Although their purpose for fishing is recreation, many recreational fishermen in Hawaii purchase commercial licenses which are required to sell fish legally. Their activities are recorded in the HFG files but it is not possible to separate the recreational data from the commercial data with certainty. Information on the amount of effort expended by the recreational segment of the billfish fishery, the amount of fish caught, and the size of individual fish caught is almost totally lacking.

A committee of NMFS personnel (Ray Sumida and Heeny Yuen) and HFG personnel (Clyde Miyazawa, Eric Onizuka, and Henry Sakuda) met to confront the problem of how to institute an effective logbook system in the recreational fishing fleet where fishing licenses are not required. This brought out the information needs that should be fulfilled before a full-scale launching of a logbook system. The proposed pilot study is for the purpose of obtaining the desired information.

Without a licensing program a voluntary logbook system seemed more appropriate than a compulsory system. The concept of a voluntary system opened up the possibility of using a sampling design to distribute the logbooks instead of placing a logbook on every boat. A reliable sampling program would reduce the cost of implementing the system. A sampling design requires a determination of sample size which in turn requires estimates of the means and variances of the variables being measured. Estimates of these statistical parameters are to be obtained in this pilot study.

The concept of a voluntary system influenced the design of the logbook. As a motivation to keep detailed logs, the logbooks will be given to the fishermen as personal logbooks with the agreement that the books will be collected periodically for data extraction and returned. A decision has yet to be made on which agency will be responsible for data management and storage. At this point HFG by virtue of its existing well organized, computerized system appears to be the most likely candidate.

The books were designed to have hard covers with data forms that included ample space for personal notes. Consideration was given to such details as content, simplicity of instructions, clarity, brevity, and styles of type to make the book attractive. In spite of this attention it is impossible to predict how fishermen will respond. The effectiveness of the logbook design in producing a positive response from fishermen is to be tested in this pilot study. At the same time fishermen will be invited to suggest modifications that would make it more conducive for the fishermen to fill out the logbook.

An important question to be answered by the pilot study is, "What is the cost of inaugurating and maintaining a logbook system?"

Implementation

1. Investigate printing costs of logbooks with attention to the most economical number and book dimensions.
2. Print 100 logbooks (draft sample provided).
3. Obtain list of registered boats for the Island of Oahu from the Harbors Division of the Transportation Department.
4. Derive a list of fishing boats from the above list and stratify the boats into a reasonable number (2-4) of categories by size and/or horsepower.
5. Randomly select boats from each strata so that the total number selected is 100.
6. Personally deliver a logbook to each of the selectees. At the same time explain the instructions for using the logbook, the purpose of the project, and how the project is being carried out.
7. Visit each selectee at one-month intervals to extract the data from his logbook. Any questions selectees may have on the use of the logbook should be clarified during these visits. Areas of difficulty in filling out the forms should be noted for the final critique on logbook design.
8. The final visit for data extraction will be at the end of 6 months. At the final visit interview the selectee to obtain a critique of the logbook and suggestions for improvement.

9. Analyze data by boat categories for number of respondents, ways of improving response to logbook, and ways of improving data extraction. Do an analysis of variance by boat categories of the number of hours of fishing, number of each species caught, and size of each species.

10. Keep a detailed account of all expenditures of time and money for each phase of the project.

11. Report findings.

Implementation of this study will require the services of one person full time with overall responsibility for the study and 3 part-time assistants. The study leader will be responsible for:

1. Publication of the logbooks.

2. Training of the assistants in conducting the distribution of the logbooks, the monthly visits, and the final interview.

3. Scheduling of visits.

4. Data analyses.

5. A detailed account of time and money expenditures.

6. The final report.

The assistants will be responsible for distributing the logbooks, the monthly data extraction visits, the final interview, and being clear on what is to be done and said in their contracts with the selected logbook holders.

Objectives

The objectives of the study are:

1. To introduce a logbook system to recreational fishermen.

2. To educate recreational fishermen to the use and value of a logbook system.

3. To estimate the number of respondents to a logbook system.

4. To realize an effective logbook design.
5. To estimate the means and variances of the number of hours fished, the number of each species caught, and the size of each species caught by individual boats.
6. To determine the sample size for an eventual logbook system.
7. To determine the cost of implementing a logbook system.

Estimated costs

The cost estimates are in thousands of dollars.

Salary of study leader full time for 8 months	\$12.0
Services of assistants at \$5 per visit	3.5
Printing of logbooks	.5
Printout of list of Oahu boats	.3
Transportation - automobile expenses	2.0
Computer services of data analyses	.2
Miscellaneous	<u>1.5</u>
	\$20.0

RECREATIONAL FISHING LOG

DIVISION OF FISH AND GAME
STATE OF HAWAII

(ADDRESS)

cover

RECREATIONAL FISHING LOG

PROPERTY OF _____

ADDRESS _____

ISLAND _____

NAME OF BOAT _____

OFFICIAL NUMBER _____

REGISTERED OWNER _____

TYPE OF BOAT _____ LENGTH _____

HORSEPOWER _____ OUTBOARD ☐ INBOARD ☐

RECREATIONAL FISHING LOG
furnished by _____

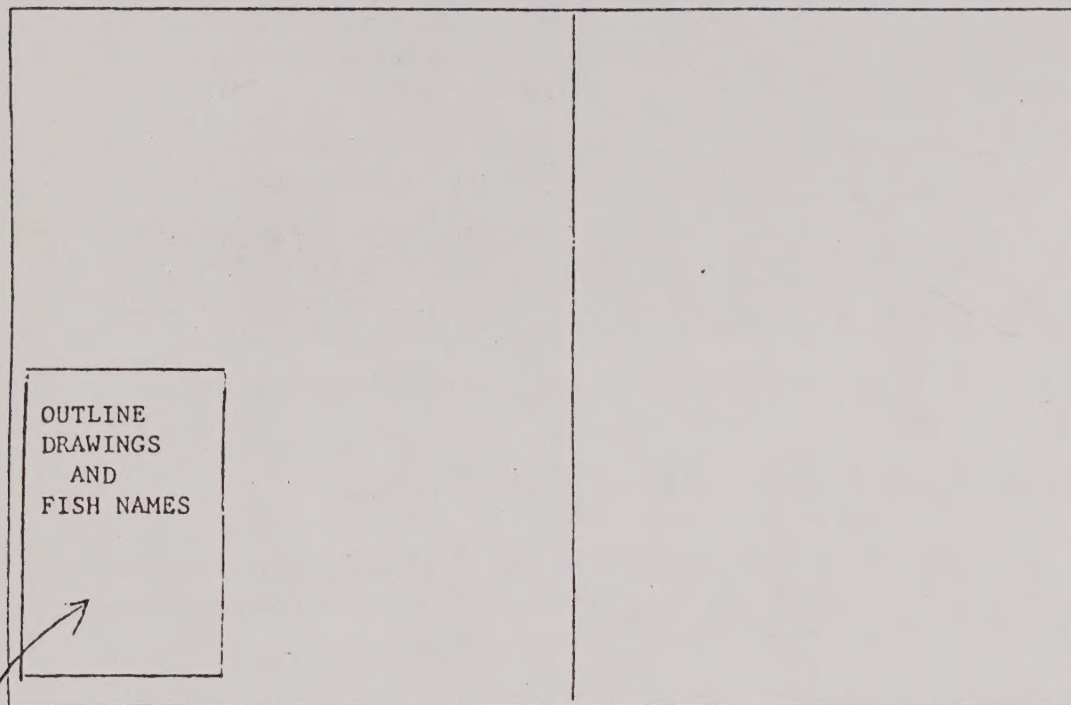
The intent of this book is to provide you with a log for your fishing activities and to furnish the Division of Fish and Game with information needed to determine the status of the recreational fishing resources. Determination of abundance requires accurate information on the number of fish caught, the size of each fish, and the amount of fishing effort expended in making the catch. You are urged to record each time you go fishing whether you catch fish or not. Feel free to enter any information of value to you regarding the operations of your boat. This is your opportunity to contribute to the conservation and perpetuation of Hawaii's game fish resources and to provide yourself with a permanent record of your fishing activities.

THIS BOOK IS YOUR PERSONAL PROPERTY SUBJECT TO INSPECTION ONLY BY
AUTHORIZED REPRESENTATIVES OF THE DIVISION OF FISH AND GAME. THE FACTUAL
DATA YOU SUPPLY WILL BE USED EXCLUSIVELY IN THE STUDY OF THE FISHERY.

A sample page and the following instructions are included to assist you in keeping this record.

1. Record each fishing day whether fish are caught or not.
2. Record the time and location for each change in fishing area. The map on the next page indicates the area numbers. You may use area numbers or the common name of the area in recording location.
3. Under "Remarks" record any information which may be useful to you regarding your present or future fishing success.

AREA MAP



Blue marlin
Striped marlin
Black marlin
Shortbill spearfish
Sailfish
Ahi (Yellowfin tuna)
Bigeye tuna
Aku
Kawakawa
Mahimahi
Ono

